

National Space Transportation Policy

Issues for the Future

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SCIENCE AND TECHNOLOGY

PREFACE

This report was undertaken to provide relevant background information and policy analysis to support revision of National Space Transportation Policy (NSTP). The report highlights: the features of past U.S. national space policies regarding assured access to space and analyzes the implications of several approaches to achieving assured access to space for critical U.S. national security, civil, and commercial missions; the evolution of existing U.S. future space launch initiatives, and; the status of current U.S. in-space transportation initiatives. The report includes recommended policy language to address assured access to space, future space launch, and in-space transportation in a revised NSTP.

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SUMMARY

In June 2002, the Bush Administration released National Security Presidential Directive/NSPD-15, which instructed the National Security Council (NSC), with the support of the Office of Science and Technology Policy (OSTP), to conduct a review of national space policies – making use of the Space Policy Coordinating Committee (PCC). The review was intended to focus on several concurrent reviews that would make recommendations in three areas: United States policy on commercial remote sensing and foreign access to remote sensing space capabilities; United States space transportation policy, and; revision, consolidation, and/or elimination of existing policy statements related to space activities. This study was undertaken to provide analytical support to the review of national space transportation policy – which would replace the National Space Transportation Policy of 1994. The report examines three key issues: assured access to space, future space launch initiatives, and in-space transportation. The purpose of the study is to inform the policymaking process and to assist OSTP in addressing key questions confronting decision makers. In furtherance of that objective, we developed recommended policy language in each of the three specific issues areas. These recommendations have been summarized below.

Assured Access to Space

An updated NSTP could include the following policy language to communicate the importance of assured access to space:

- “The Space Shuttle and the EELV fleets will be operated until a well-defined transition can be implemented to proven and operationally available replacement systems.”
- “DoD will work with its industry partners to design, deploy, and maintain two independent and redundant families of U.S. manufactured EELV systems.”
- “DoD will work with its industry partners to develop and maintain EELV launch facilities on both the East and West Coasts.”
- “DoD will take the following actions to emphasize the importance of mission success while flying out existing heritage launch systems and completing the transition to EELV:
 - Program Management: ensure adequate and qualified staff, clear lines of authority and responsibility, and an emphasis on mission success and process discipline during heritage system fly-out and transition to EELV;
 - Schedule and Resources: ensure balance to avoid adversely impacting mission success;
 - Risk Management: ensure program management is aware and informed regarding risks to mission success; and

- Systems Engineering: ensure the most important considerations relating to mission success are identified and addressed, including means to build confidence in reliability expectations (e.g., demonstration flights of new vehicles).”
- “NASA will pursue Space Shuttle upgrades, in accordance with CAIB recommendations, to address safety, reliability, and obsolescence.
 - NASA will implement facility maintenance as required to sustain reliable operation of the Space Shuttle fleet; and
 - NASA will work with DoD to document lessons learned from the transition from heritage ELVs to the EELV fleet to enable effective planning for an eventual transition from the Space Shuttle to a replacement system for human access to space.”
- “DoD will maintain and modernize launch ranges to reduce operating costs and ensure adequate capacity and flexibility to assure access to space.
 - NASA will lead the development of technology roadmaps to define plans for development and demonstration of next-generation range technologies to enable development of space-based and mobile range assets.”
- “NASA will conduct cost and effectiveness trade studies to support a decision by the President or his designee relating to the development of an automated interim domestic backup for the Space Shuttle’s capability to deliver cargo and logistics supplies to the International Space Station.”
- “DoD will seek arrangements with U.S. EELV launch service providers to provide access to foreign launch vehicles as a backup to assure access to space in case of failures or prolonged stand-downs of U.S. launch capabilities.”

Future Space Transportation

An updated NSTP could include the following policy language to communicate the importance of developing future space transportation technology.

- “The Department of Defense and the National Aeronautics and Space Administration will cooperate in technology development efforts aimed at dramatically reducing the cost of space launch systems.
 - These cooperative efforts will further seek to improve the safety, responsiveness, and reliability of space launch systems for national security, civil, and commercial purposes.
 - The National Aeronautics and Space Administration shall cooperate with other government agencies where appropriate.”
- “The National Aeronautics and Space Administration will establish a formal procedural framework for developing advanced future space launch technologies, which will be utilized to annually update a strategic plan for achieving dramatic cost reductions and improved safety, responsiveness, and reliability of space launch systems.”

- “The National Aeronautics and Space Administration will develop a Crew-Transfer-Return-Vehicle capable of being launched aboard an Evolved Expendable Launch Vehicle, to enable an early transition from the Space Shuttle.
 - This vehicle shall be capable of returning a crew of between four and seven astronauts from the International Space Station in an emergency situation.
 - Until a Crew-Transfer-Return-Vehicle is available, the National Aeronautics and Space Administration will investigate opportunities for utilizing additional Soyuz spacecraft to provide a six crew escape capability for the International Space Station.”
- “The National Aeronautics and Space Administration will conduct advanced propulsion research focused on 3rd generation concepts.
 - The Department of Defense will conduct hypersonic and air-breathing propulsion system research that could be used as the first stage of a next-generation launch vehicle and identify synergistic opportunities with NASA and the commercial sector.”

In-Space Transportation

An updated NSTP could include the following policy language to communicate the importance of developing in-space transportation technologies:

- “The National Aeronautics and Space Administration will pursue affordable, reliable, and timely transport of people, machines, and consumables across near-Earth and interplanetary space.
 - NASA will work to enable routine, flexible, and affordable voyages of people and machines to planetary surfaces.”
- “The National Aeronautics and Space Administration, to the degree possible, will establish a consistent level of funding for advanced and nuclear in-space propulsion programs to ensure that steady progress is made toward affordable, reliable, and timely in-space transportation capabilities.”
- “The National Aeronautics and Space Administration will establish an internal process to prioritize in-space transportation technology research and development.
 - This prioritization process will seek to match technologies with missions, ensuring that appropriate systems are developed for transport of people, machines, and consumables across near-Earth and interplanetary space.
 - This prioritization process will examine mission requirements across National Aeronautics and Space Administration strategic enterprises to ensure that the most critical needs are addressed by ongoing technology development programs.”
- “The National Aeronautics and Space Administration will adopt a balanced approach to research and development of advanced and nuclear in-space propulsion technologies, which meets the requirements for transport of humans, machines, and consumables.”

- “The National Aeronautics and Space Administration, where appropriate, will cooperate with the Department of Energy on nuclear propulsion and power technology research and development.”
- “The National Aeronautics and Space Administration will investigate opportunities for cooperation with the Russian Federation, and other countries where appropriate, on nuclear propulsion and power technology research and development.”
- “The National Aeronautics and Space Administration will establish processes that will promote the highest levels of safety in the use of nuclear propulsion and power technology.”

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ACRONYM LIST

<u>SYMBOL</u>	<u>DEFINITION</u>
AEC	Atomic Energy Commission
ALS	Advanced Launch System
ARPA	Advanced Research Projects Agency
BAR	Broad Area Review
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CBO	Congressional Budget Office
CELV	Complementary Expendable Launch Vehicle
CRV	Crew Return Vehicle
CTRV	Crew Transfer Return Vehicle
DDR&E	Director, Defense Research and Engineering
DoD	Department of Defense
DPG	Defense Planning Guidance
DPT	Decadal Planning Team
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
ESA	European Space Agency
FAIR	Federal Activities Inventory Reform
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Year
GAO	General Accounting Office
GEO	Geostationary Orbit
ISP	Specific Impulse
ISS	International Space Station
ISTP	Integrated Space Transportation Plan
JPL	Jet Propulsion Laboratory
LEO	Low-Earth Orbit
M2P2	Mini-Magnetosphere Plasma Propulsion
MMW	Multi-Megawatt
MPD	Electromagnetic Magnetoplasmadynamic
MXER	Momentum Exchange, Electrodynamic Reboost
NAI	National Aerospace Initiative
NASA	National Aeronautics and Space Administration

NASP	National Aerospace Plane
NERVA	Nuclear Engines for Rocket Vehicle Applications
NExT	NASA Exploration Team
NLS	National Launch System
NRO	National Reconnaissance Office
NSDD	National Security Decision Directive
NSI	Nuclear Systems Initiative
NSPD	National Security Policy Directive
NSTC	National Science & Technology Council
NSTP	National Space Transportation Policy
O&M	Operations & Maintenance
OMB	Office of Management and Budget
OSP	Orbital Space Plane
OSTP	Office of Science and Technology Policy
PDD	Presidential Decision Directive
QDR	Quadrennial Defense Review
R&D	Research & Development
RLV	Reusable Launch Vehicle
RSTARS	Reusable Space Transportation and Recovery System
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Office
SEI	Space Exploration Initiative
SLI	Space Launch Initiative
SNPO	Space Nuclear Propulsion Office
SRR	System Requirements Review
SSTO	Single-Stage-To-Orbit
STAS	Space Transportation Architecture Studies
TRL	Technical Readiness Level
TSPR	Total System Performance Responsibilities
TSTO	Two-Stage-To-Orbit
USAF	United States Air Force
VASIMR	Variable Impulse Magneto-Plasma Rocket

CHAPTER ONE: INTRODUCTION

Since the dawning of the space age nearly five decades ago, the United States has relied on its strong domestic space launch capabilities to support a variety of defense, intelligence, civil, and commercial requirements. Developing, maintaining, and operating a robust fleet of launch vehicles has quite literally enabled nearly all American activities in space. These space transportation systems made possible human exploration of the Moon, robotic exploration of the solar system, and space-based observation of both our home planet and the farthest reaches of the universe. These assets made possible national security missions ranging from high-resolution imaging of enemy territory to increased situational awareness to global communications. As a result of our increasing reliance on space, preserving our ability to access space and transport people, machines, and consumables across near-Earth and interplanetary space is critical to maintaining global leadership.^{1/2}

On 5 August 1994, in recognition of the vitally important role played by space transportation systems, the Clinton Administration released National Science and Technology Council/NSTC-4 – which has commonly been known as the National Space Transportation Policy of 1994 (NSTP). The document stated that the “space program is critical to achieving US national security, scientific, technical, commercial, and foreign policy goals. Assuring reliable and affordable access to space through US space transportation capabilities is a fundamental goal of the US space program.” To support that objective, the administration laid out six broad policy goals: 1) modernize space transportation capabilities through investment in future technologies; 2) maintain strong launch systems, infrastructure, and support facilities; 3) encourage cost reduction in current space transportation systems; 4) foster development of a next generation reusable space transportation system; 5) encourage cost-effective use of commercial American products that meet mission requirements; and 6) foster the international competitiveness of the US aerospace industry by considering factoring commercial needs into space launch decisions. The policy included specific guidelines to ensure successful implementation of the policy and sought to take advantage of the unique capabilities and resources of the civilian and military space sectors.³

The primary goal established by the NSTP for the Department of Defense (DoD) was to “be the lead agency for improvements and evolution of the current US expendable launch vehicle (ELV) fleet, including appropriate technology development.” The United States Air Force (USAF) adopted the Evolved Expendable Launch Vehicle (EELV) program to achieve the goals set by the NSTP. The EELV program

¹ For the purposes of this report, space transportation is defined as: a) launching people, machines, and consumables into Earth orbit and b) transporting people, machines, and consumables across near-Earth and interplanetary space.

² *Final Report of the Commission on the Future of the United States Aerospace Industry* (Washington, DC: Government Printing Office, 2002), 3-1 to 3-13.

³ National Space Transportation Policy, Presidential Decision Directive (PDD) National Science & Technology Council (NSTC) 4 (5 August 1994).

was intended to create a government-industry partnership to develop a national launch capability that satisfied government requirements, reduced launch costs by twenty-five percent, and increased the competitiveness of domestic companies in the international launch market. In 2002, the Lockheed Martin Atlas V and Boeing Delta IV EELV launch families entered service with successful maiden missions.⁴

The first of two goals established by the NSTP for the National Aeronautics and Space Administration (NASA) was to “continue to maintain the capability to operate the Space Shuttle fleet and associated facilities.” Keeping the Shuttle flying safely and reliably for at least another decade (until a replacement vehicle would nominally be available) represented a major challenge for the agency. Over the course of the late 1990s, NASA sponsored a series of Shuttle upgrade studies, which resulted in the adoption of a four-phased strategy to make safety, performance, supportability, and obsolescence upgrades. The Space Shuttle Program Office concluded that with minimal upgrades, NASA could continue safely operating the fleet until 2020. Following the loss of the Shuttle *Columbia* in February 2003, and the recent release of the Columbia Accident Investigation Board report, the future of the Shuttle system is in flux as NASA program managers attempt to implement the board’s recommendations for Shuttle return to flight.⁵ The second goal established by the NSTP for NASA was to be the “lead agency for technology development and demonstration for next generation reusable space transportation systems, such as the single-stage-to-orbit concept.” NASA adopted the X-33 program to demonstrate the key design and operational aspects of a single-stage-to-orbit (SSTO) reusable launch vehicle (RLV). The program was designed to inform an “end of decade” decision regarding government development of an operational next-generation reusable launch system. NASA chose Lockheed Martin as the prime contractor for the X-33 program. Planned implementation of X-33 required that both NASA and Lockheed Martin commit to technical task accomplishment within a fixed set of cost and schedule constraints. The intention was that this approach would reduce the program’s business and technical risks, enabling Lockheed Martin to attain private financing for development and operation of a fully operational and low-cost next generation space transportation system. Lockheed Martin, as the industry partner, would have sole responsibility to build that system – which they dubbed *Venture Star*. The ultimate goal was for *Venture Star* to be capable of delivering payloads into low earth orbit for \$1,000 per pound (an order of magnitude reduction from the \$10,000 per pound cost of existing launch systems). In March 2001, the X-33 program was cancelled by NASA due to serious technical difficulties and impending budgetary considerations. NASA investment for

⁴ EELV Program Office, “Introduction to the EELV SPO,” 3 March 2003.

⁵ National Aeronautics and Space Administration, *Space Transportation Architecture Study*, 1999, prepared by the Office of the Chief Engineer (Washington, DC: accessed 15 May 2003), available from http://www.hq.nasa.gov/office/codea/codeac/sta_study.html, Internet; National Academy of Science, *Upgrading the Space Shuttle*, 1999, prepared by the Committee on Space Shuttle Upgrades (Washington, DC: accessed 15 May 2003), available from <http://www.nap.edu/readingroom/books/upgrading/notice.htm>, Internet; *Columbia Accident Investigation Board Report, Volume 1* (Washington, DC: Government Printing Office, August 2003); NASA Implementation Plan for Return to Flight and Beyond (Washington, DC: National Aeronautics and Space Administration, September 2003).

the project totaled \$912 million, which stayed within its budget projection – although no flight vehicle was ever tested.⁶

The NSTP also included guidelines for fostering the commercial U.S. space transportation industry. As part of this effort, the Departments of Transportation (DOT) and Commerce (DOC) were “responsible for identifying and promoting” partnerships between the government and private sector. In addition, the DOT was given authority to grant licenses for commercial space launches – in coordination with the DOC. The policy also addressed international trade in commercial space launch services, setting as a long term goal free and fair trade in this area. However, the NSTP mandated that all U.S. government payloads continue to be launched only on U.S. manufactured launch vehicles. Finally, the policy directed that excess ballistic missile assets could not be utilized to launch payloads into orbit without specific authorization from the Secretary of Defense – who could only provide approval in limited circumstances.⁷

Study Purpose and Research Approach

For over two decades, every presidential administration has either significantly revised or totally rewritten national space policy. On 28 June 2002, the Bush Administration released National Security Presidential Directive/NSPD-15, which introduced a process for revision, consolidation, and/or elimination of existing policy statements. NSPD-15 instructed the National Security Council (NSC), with the support of the Office of Science and Technology Policy (OSTP), to conduct a review of national space policies – making use of the Space Policy Coordinating Committee (PCC). NSPD-15 stated that:

The United States depends on defense, intelligence, civil, and commercial space capabilities to protect and defend national security and enhance economic competitiveness. The most recent update of the National Space Policy occurred in 1996. Since that time, domestic and international developments have changed significantly the opportunities for, challenges to, and threats confronting U.S. space capabilities. To respond to the new environment, this directive initiates a phased review of national space policy topics.

Initially, the review was intended to focus on concurrent evaluations that would make recommendations in two areas – United States policy on commercial remote sensing and foreign access to remote sensing space capabilities and United States space transportation policy.⁸

⁶ “X-33, X-34 Left Behind in NASA Space Launch Initiative,” *Spaceflight Now* (1 March 2001); “Assembling VentureStar Puzzle Makes X-33 Look Easy,” *Aviation Week and Space Technology*, 4 October 1999; Jonathon Lipman, “NASA May Develop an X-33B,” *Space.com*, 27 October 1999.

⁷ National Space Transportation Policy, Presidential Decision Directive (PDD) National Science & Technology Council (NSTC) 4 (5 August 1994).

The purpose of this study was to assist the White House Office of Science and Technology Policy in supporting the national space transportation policy review. OSTP asked the RAND Science and Technology Policy Institute (STPI) to review three distinct issue areas that would form the core of a revised NSTP – assured access to space, future space launch, and in-space transportation. With assured access to space, STPI was asked to discuss the historical development and evaluate the policy implications of the concept. With future space launch, STPI was asked to provide an overview of the two major contemporary development initiatives. With in-space transportation, STPI was asked to discuss historical programs and provide an overview of contemporary development efforts. In each of these three areas, STPI was also asked to provide policy language recommendations.

Study efforts began with a comprehensive literature review that examined major space transportation developments during the past decade, with an emphasis on important space transportation-related studies and policy documents. The next step was an analysis of notable themes emerging from the Bush administration, ranging from the President’s Management Agenda to the DoD Space Policy to NASA’s Strategic Plan. Additionally, we received briefings regarding current program planning for meeting the nation’s space transportation needs – both for reaching Earth orbit and transporting people, machines, and consumables across near-Earth and interplanetary space. The vast majority of the work done on this study was completed more than a month before the loss of the Space Shuttle *Columbia* on 1 February 2003. As a result, it does not fully take into account the findings of the Columbia Accident Investigation Board (CAIB). While the analysis presented was largely conducted pre-*Columbia*, we nevertheless recognize that the loss of the *Columbia* and the CAIB recommendations could significantly affect the evolution of U.S. space transportation policy. For that reason, we have revised appropriate sections of the report to ensure that it is up-to-date with rapidly unfolding events in this issue area.

Organization of the Report

This report consists of four chapters, including the Introduction. Although there is some overlap between these key issue areas, the intent was that they would represent distinct policy and programmatic overviews.

Chapter Two provides an overview of the features of past U.S. national space policies regarding assured access to space, highlights findings from recent launch failures (not including the Space Shuttle *Columbia* accident investigation), and analyzes the implications of several approaches to achieving assured access to space for critical U.S. national security, civil, and commercial missions. It includes recommended policy language to address assured access to space within a revised policy.

⁸ The White House, National Security Presidential Directive/NSPD-15: National Space Policy Review, 28 June 2002..

Chapter Three provides an overview of contemporary U.S. space launch initiatives being carried out by both NASA and the Department of Defense. It includes recommended policy language to address future space launch requirements within a revised policy.

Chapter Four provides an overview of past in-space transportation technology demonstration programs, and provides an overview of contemporary U.S. in-space transportation initiatives being carried out by NASA. It includes recommended policy language to address in-space transportation requirements within a revised policy.

This report also contains two important appendices that were drawn on heavily to derive the study's recommended policy language. Appendix A provides an overview of macro-level trends within the larger space policy arena during the past decade that have specific relevance for national space transportation policy. These trends form the backdrop and context that a revised NSTP would likely be viewed by those familiar with the U.S. national security, civil, and commercial space sectors. Appendix B summarizes some of the important Bush administration themes drawn from the President's Management Agenda, various national security policies, and the NASA strategic plan.

CHAPTER TWO: ASSURED ACCESS TO SPACE

Assured access to space, a concept first introduced in the late 1980s, has primarily been used in the context of ensuring the continuous capability of the DoD to perform critical national security missions – including launching space systems into specific orbital inclinations and altitudes, as well as ensuring reliable access to crucial sensor data collected by different military and intelligence satellite constellations. From this perspective, space transportation (including associated launch facilities and ranges) is clearly an essential component of the logistics tail associated with maintaining constellations of operating satellites adequate to provide these vital data streams for national security missions. Not surprisingly, assured access to space in the context of robust space transportation capabilities has become an increasingly important part of national space policy. So much so, that the White House has indicated that a revised national space transportation policy will feature policy language intended to foster the technologies and management structures necessary to provide assured access to space. This chapter seeks to better understand the historical development of assured access as a concept, and the differing views that the various space sectors (national security, civil, and commercial) have regarding how best to provide that assured access. The ultimate goal of this chapter is to use this historical analysis, combined with an evaluation of the implications of different approaches, to provide policymakers with policy language recommendations to appropriately address assured access to space in a revised NSTP.

Development of the Assured Access Concept

As pointed out in the 11 January 2001 *Report of the Commission to Assess United States National Security Space Management and Organization* (Space Commission Report), the U.S. has become more reliant on space capabilities for both national security and economic purposes. As a result, we are now more vulnerable to the effects of disruption or denial of data streams to and from our national security and commercial satellites. Consequently, assured access to space is an important link in the chain of capabilities required to ensure that we can continue to conduct critical missions. In other words, with regard to national security mission capabilities, robust and reliable space transportation is a key enabling capability to assure access to space.

Since the late 1990s, the concept of assured access to space has also been applied to critical civil sector missions, including the ability to move cargo to and from the International Space Station (ISS) for logistics support. This is a fundamentally different application than maintaining a reliable data stream from national security satellites. Still, the ability to ensure cargo delivery to the ISS has been pursued as a capability essential to meeting that program's requirements. Interestingly, assured access to (and from) space for human crews has only been obliquely referred to in past national space policy directives - it has not been explicitly addressed. Now that the ISS is operating in orbit and providing continuous human presence in space, it may be an appropriate time to seriously consider whether assured access to (and from) space for

human crews should be explicitly included in a revised NSTP – particularly in the aftermath of the Shuttle *Columbia* accident. Over the past two decades, there have been three primary national policies that have addressed the issue of assured access to space, including: the National Space Policy of 1988, National Space Launch Strategy of 1991, and the National Space Transportation Policy of 1994.

Assured access to space has been explicitly addressed as an important element of national space policy since the Reagan Administration issued its Presidential Directive on National Space Policy in early 1988.⁹ The inclusion of the concept was particularly timely, because the nation was still recovering from a series of launch failures that involved virtually every expendable launch vehicle in the U.S. inventory and the Space Shuttle *Challenger*. The 1988 policy required that “United States space transportation systems must provide a balanced, robust, and flexible capability with sufficient resiliency to allow continued operations despite failures in any single system.” It further specified:

The national security space sector may use both manned and unmanned launch systems as determined by specific mission requirements. Payloads will be distributed among launch systems and launch sites to minimize the impact of loss of any single launch system or launch site on mission performance. The DoD will procure unmanned launch vehicles or services and maintain launch capability on both the East and West coasts.

This approach had been advocated by the United States Air Force (USAF) before the *Challenger* accident. The Titan IV complementary expendable launch vehicle (CELV), developed as a backup for the Space Shuttle for critical national security space missions, was the primary tool used to implement the policy. Although the 1988 policy selected this robust approach to assure access for national security payloads, it did not include a provision to provide a backup capability for human access to space (or satellite retrieval).

Released on 19 July 1991, the Bush Administration’s National Space Launch Strategy pointed out that “assured access to space is a key element of U.S. national space policy and a foundation upon which U.S. civil, national security, and commercial space activities depend.”¹⁰ The policy guidelines included the following points:

A mixed fleet comprised of the Space Shuttle and existing expendable launch vehicles will be the primary U.S. government means to transport people and cargo to and from

⁹ Presidential Directive on National Space Policy, Fact Sheet on National Security Decision Directive (NSDD) 293 (11 February 1988), available from www.hq.nasa.gov/office/pao/History/policy88.html.

¹⁰ National Space Launch Strategy, Presidential Decision Directive (PDD) National Space Policy Directive (NSPD) 4 (19 July 1991), available from www.fas.org/spp/military/docops/national/nspd4.htm.

space through the current decade and will be important components of the nation's launch capability well into the first decade of the 21st century.

The Space Shuttle will be used only for those important missions that require manned presence or other unique Shuttle capabilities, or for which use of the Shuttle is determined to be important for national security, foreign policy, or other compelling purposes.¹¹

The Department of Defense and the National Aeronautics and Space Administration will undertake the joint development of a new space launch system to meet civil and national security needs. While initially unmanned, the new launch system will be designed to be 'manrateable' in the future.

In actuality, this new launch system was merely a derivative of the Advanced Launch System (ALS) program, which had been established by the Reagan Administration to address the mission requirements of the Strategic Defense Initiative (SDI). The newly renamed National Launch System was also seen as a critical element of the Bush Administration's Space Exploration Initiative.¹²

The Clinton Administration's National Space Transportation Policy of 1994 took a different approach to assured access to space, emphasizing the importance of reliability and affordability. The policy stated, "Assuring reliable and affordable access to space through U.S. space transportation capabilities is a fundamental goal of the U.S. space program."¹³ As discussed above, the policy listed six implementation guidelines to accomplish this goal. The first three focused primarily on the sustainment of current space transportation capabilities, while pursuing improvements and modernization:

- Balance efforts to sustain and modernize existing space transportation capabilities with the need to invest in the development of improved future capabilities;
- Maintain a strong space transportation capability and technology base, including launch systems, infrastructure, and support facilities, to meet the national needs for space transport of personnel and payloads; and

¹¹ This policy was later formalized by federal legislation establishing an official Space Shuttle Use Policy (Title 42 – The Public Health And Welfare, Chapter 26 – National Space Program, Subchapter I – General Provisions, Section 2465a. Space Shuttle Use Policy).

¹² Announced by President Bush on 20 July 1989, SEI was a program intended to establish a lunar outpost and send humans to explore Mars; Space Exploration Initiative, Presidential Decision Directive (PDD) National Space Policy Directive (NSPD) 6 (13 March 1992).

¹³ National Space Transportation Policy, Presidential Decision Directive (PDD) National Science & Technology Council (NSTC) 4 (5 August 1994).

- Promote the reduction in the cost of current space transportation systems while improving their reliability, operability, responsiveness, and safety.

The second three focused on RLV technology development to reduce the cost of access to space, increase government use of commercial launch services, and maintain the competitiveness of the U.S. space transportation industry. While previous policies addressed these last two points, they had not done so in the context of assuring access to space. The principal distinguishing feature of the 1994 policy was the clear division of responsibilities between DoD and NASA regarding the development of new ELVs and RLVs.

Post-NSTP of 1994 Developments

During the decade following the release of the NSTP, there have been significant events within the space launch sector that have indicated the need for a more centralized statement of the importance of assured access to space in national space policy. For example, during an eight-month span from late 1998 to early 1999, the U.S. experienced the worst series of launch failures since the mid-1980s. This included upper stage failures on three DoD missions launched on Titan IV core vehicles (resulting in a total loss in excess of \$3 billion worth of launch vehicle and spacecraft hardware) and two commercial Delta III vehicles (resulting in losses of launch vehicles and spacecraft worth more than \$500 million). In November 1999, DoD released the Space Launch Vehicles Broad Area Review (BAR) Report, which highlighted the significant connection between these losses and U.S. assured access to space.¹⁴ It stated:

The failure of three Government missions, combined with the failure of two commercial missions within the same time frame, sparked widespread concern in our ability to assure access to space ... Because assured access to space is critical to the overall strength and stability of our national security, commercial, and civil space sectors, both the Executive and Legislative branches asked the Department of Defense (DoD), in coordination with the Director of Central Intelligence and the Administrator of the National Aeronautics and Space Administration, to examine the failures and to provide a report on the causes and corrective actions being taken to prevent their reoccurrence and to ensure future access to space.

The report addressed two overarching corrective actions that would ensure future access to space. First, it recommended focusing serious attention on the successful fly-out of existing ELV systems – vehicles with no spares that were critical for missions worth approximately \$20 billion. The BAR identified five critical

¹⁴ Space Launch Vehicles Broad Area Review: Executive Summary, available from www.af.mil/lib/misc/spacebar99b.htm; Internet; accessed 24 October 2002.

elements to assure access to space as the U.S. continued to fly-out existing systems: 1) Program Management, 2) Schedule and Resources, 3) Risk Management, 4) System Engineering, and 5) Titan Cost Pressures. Second, it recommended bolstering confidence in launch success during the transition to EELV operations. The review noted “the nation’s future access to space depends on successful transition from the fly-out systems to the families of EELVs.” The BAR argued that better technical and management staffing was needed for the fly-out to EELV transition, that a well-defined transition plan was required, and that clearly delineated end-to-end responsibility and authority for delivery of payloads to orbit using EELVs should be finalized. Finally, the BAR identified nine critical elements to assure access to space through the transition to EELV, including several that paralleled those found in the fly-out section: 1) Management, 2) Partnering, 3) Independent Review, 4) Building Confidence in Reliability Expectations, and 5) Cost Pressures. The BAR concluded its report with five bottom line recommendations to assure access to space:

- Government should ensure industry acts to correct causes of recent failures and improve systems engineering and process discipline.
- Government should establish clear accountability for mission success for fly-out systems and transition to EELV.
- Enhance government industry partnership with needed management, engineering support and emphasis on mission success.
- Provide a well defined, coordinated, disseminated transition plan to EELV.
- Government should invest to build confidence in EELV reliability with enhancements and increase oversight.

The findings and recommendations from these launch system failure reviews represent very expensive lessons learned that may be appropriate to take into account in a revision of NSTP – particularly with regard to implementation of the fly-out of heritage launch systems and the simultaneous transition to the EELV.

Another troubling trend began in 1999, when NASA and United Space Alliance (USA)¹⁵ began discovering potentially serious problems with the Space Shuttle that led to groundings of the entire fleet while these difficulties were investigated and corrected. These incidents included:

- July 1999: NASA observed a short circuit in wiring to the main engine controller during the STS-93 mission, which resulted in a grounding of the Shuttle fleet for almost seven months while the other orbiters were inspected for similar problems.

¹⁵ USA, a partnership between Lockheed Martin and Boeing, manages NASA’s Space Flight Operations Contract (SFOC).

- July 1999: Also on STS-93, an eight-inch long gold-plated metal pin came loose during launch and was ejected through the engine's combustion chamber, impacted the nozzle (rupturing three of the cooling tubes), and created a hydrogen fuel leak into the rocket engine's exhaust. This could have led to a main engine shut down during ascent, requiring a never attempted abort back to Kennedy Space Center (or an alternate landing site).¹⁶
- November 2000: the launch of STS-92 was delayed to remove a four-inch long metal pin lodged against the Space Shuttle Discovery's external tank, which was discovered during a pre-launch inspection on the pad and could have led to a launch failure.
- June 2002: tiny cracks were discovered in Shuttle Atlantis' aft propellant lines during a routine visual inspection by a technician. The Shuttle fleet was grounded for four months to repair similar problems found in the other orbiters.¹⁷
- August 2002: an inspection of two of the 37-year old crawler transporters, used to move the Shuttle from the Vehicle Assembly Building to the launch pad, found a total of 32 broken "Jacking, Equalization and Leveling" bearings.¹⁸

These incidents, related in large part to aging and maintenance issues, served as danger signs regarding the ability of the Space Shuttle system to provide assured access to space for critical civil sector missions (e.g., ISS construction and operations, Hubble Space Telescope servicing). These dangers were tragically confirmed with the loss of the Shuttle *Columbia* on 1 February 2003, and placed the continuation of both the Shuttle and ISS programs in serious jeopardy. Following the release of the CAIB report and the *NASA Implementation Plan for Return to Flight and Beyond*, the space agency is working feverishly to ensure that the Shuttle system can continue to provide launch services crucial for continued assembly and operation of the ISS.

In 1996, as discussed in Chapter One, the X-33 program was selected by NASA to work with the private sector to develop a flight demonstrator that would support a decision by the end of the 1990s on the development of a next-generation reusable launch vehicle.¹⁹ Similar to the EELV, the technology demonstrator program was structured as a government-industry partnership, with NASA contributing \$912 million and Lockheed Martin investing \$357 million toward the construction and development of the flight vehicle. In March 2001, however, following serious technical problems with the vehicle's multi-lobed

¹⁶ "NASA: Loose Pin Caused Space Shuttle Hydrogen Leak," *CNN* (30 July 1999); available from www.cnn.com/TECH/space/9907/30/shuttle.leak.01/; Internet; accessed 25 October 2002.

¹⁷ "Picky Inspector Might Have Saved Shuttle Program," *Associated Press* (1 August 2002).

¹⁸ "NASA Studies Crawler Transporter Problem, Atlantis' Cracks Welded," *Space.com* (12 August 2002).

¹⁹ Fact Sheet on National Space Policy, Presidential Decision Directive (PDD) National Security Council (NSC) 49, National Science & Technology Council (NSTC) 8 (19 September 1996).

composite liquid hydrogen fuel tank, NASA canceled the program.²⁰ NASA's smaller X-34 technology demonstrator program was also cancelled during the same time period due to technical problems. In 1999, in an effort to address technical concerns with the X-vehicle technology demonstrator programs, NASA released the results of several Space Transportation Architecture Studies (STAS). These studies (conducted by both NASA and the commercial sector) developed preliminary options that could meet civil, commercial, and national security mission requirements. The result was the adoption of an Integrated Space Transportation Plan (ISTP), a comprehensive investment strategy that included investments in near-term Space Shuttle safety upgrades, the Space Launch Initiative (SLI), and long-range investments in 3rd Generation RLV technologies (*for more information, see Chapter Three*).²¹

Policy Options and Implications

The Reagan Administration first included explicit emphasis on the importance of assured access to space in the 1988 National Space Policy that followed a series of ELV failures and the *Challenger* accident. Today, the United States is even more dependent on access to space. The series of ELV launch system failures, cancellation of several RLV technology demonstrators, and loss of the Space Shuttle *Columbia* call into question the nation's ability to guarantee access to space. Thus, making "assured access to space" a central principle of a revised NSTP is incredibly timely and important. The following paragraphs provide an evaluation of the elements that could be considered for inclusion in the new policy, based on the background discussion above.

Use of a "Mixed Fleet"

In the early 1980s, the intention was that the national space program would rely solely on the Shuttle for national security, civil, and commercial payloads. Following the *Challenger* accident, the National Space Policy of 1988 and the National Space Launch Strategy of 1991 mandated that ELVs be maintained as a Shuttle backup. The recent loss of the Shuttle *Columbia* indicates that it may be appropriate to maintain this mixed fleet approach as a central feature of national space transportation policy. Thus, a revised policy could emphasize the importance of assured access to space by directing that both the Space Shuttle and EELV fleets be operated until a well-defined transition to a proven replacement system can be implemented.

Distribution of Payloads

The National Space Policy of 1988 mandated the distribution of critical payloads among launch systems and launch sites on the East and West coasts. This policy has direct relevance to the current EELV

²⁰ "NASA Shuts Down X-33, X-34 Programs," *Space.com* (1 March 2001).

²¹ Statement of Mr. Dennis E. Smith, Program Manager, 2nd Generation RLV Program, NASA Marshall Space Flight Center, before the Subcommittee on Space and Aeronautics, Committee on Science, U.S. House of Representatives, 20 June 2001.

program. Distributing critical payloads among redundant launch systems and launch sites is one of the most obvious and effective ways to assure access to space.²² With regard to EELV, the issue is whether the federal government should ensure that there are two independent launch systems (including vehicles and facilities) available across the medium- and heavy-lift performance classes. To answer this question, policymakers could consider addressing several foundational issues.

First, do the benefits gained by sustaining both Lockheed Martin and Boeing EELV families outweigh the costs? Commercial launch market demand is less robust today than had been projected when the EELV program was restructured to include both competitors. As a result, it has been suggested by Under Secretary of the USAF Peter Teets that it could cost the government an additional \$200 million per year to sustain both EELV providers.²³ Considering the value of the launch vehicles and payloads involved, and the criticality of the national security missions enabled by EELV, this annual investment could be viewed as a relatively small price to pay to assure access to space. In addition, there may be other policy approaches that could effectively ensure the continuous operation of critical national security missions in space. For instance, increasing EELV launch rates by requiring the use of EELV to re-supply the ISS could produce cost efficiencies based on economies of scale, which in turn would reduce the amount of additional funding required to sustain both EELV operators.²⁴

Second, do the benefits gained by eliminating common systems used by the two competing families of EELVs (e.g., the RL-10 upper stage engine) outweigh the costs? Both the Lockheed Martin Atlas V and the Boeing Delta IV use the RL-10 upper stage engine. The failure of this system could lead to the grounding of both families until the cause of the failure is found and corrected. Under Secretary Teets has discussed the possibility of undertaking an engine development program to eliminate this potential single point failure in the EELV fleet.

Third, do the benefits gained by mandating redundancy in heavy-lift capabilities and dual-coast launch facilities outweigh the costs? In 2000, as noted above, the EELV program was restructured so that only one heavy lift vehicle (Boeing's Delta IV Heavy) would be built and operated, and only one set of processing and launch facilities would be built on the West Coast (at SLC-6, for Boeing's Delta IV). This means the current plan for EELV does not include redundancy for heavy lift payloads or for access to sun-synchronous, polar, and other high-inclination orbits for medium or heavy payloads. It can be argued that the most critical national security missions rely on both heavy lift and West Coast access to space. The most compelling reason to maintain launch facilities on both the East and West Coasts is to enable the

²² Not all launch systems, nor all launch sites, can reach the same orbits. This means that every payload may not be assured access to space using the available "redundant" systems.

²³ "Funds Sought as Top DoD Officials Mull Changes in Launch Program," *Inside The USAF* (25 October 2002).

²⁴ This would require modifications to the EELV payload fairings to enable the transport of ISS-related cargo.

United States to safely conduct a variety of missions requiring access to different types of orbits – from geosynchronous orbit over the equator to high-inclination orbits over or near the poles. Pursuing redundancy for EELV medium- and heavy-lift launch capabilities on both the East and West Coasts would help to assure access to space in case one system’s launch pads or processing facilities were damaged or destroyed (whether by a launch accident, natural disaster, or terrorist attack).²⁵ Thus, policymakers could consider reversing decisions made in 2000 that allowed Lockheed Martin to forgo construction of a heavy lift EELV and West Coast operating facilities for the Atlas V family. While the cost of implementing that reversal would be substantial, in May 2002 Under Secretary Teets told the Commission on the Future of the Aerospace Industry that “It is critical that we maintain two financially stable launch providers who can back each other up for both East and West Coast launches, in the event we have a major problem with one of the two systems, Delta IV or Atlas V.”²⁶ Following the USAF decision to strip Boeing of seven EELV launches (worth \$1 billion) as punishment for possessing more than 25,000 pages of proprietary documents from rival Lockheed Martin, this has become even more important.²⁷

Balance Sustainment and Future Capabilities

The breadth and seriousness of the U.S. launch system failures and near misses in the late 1990s (and the loss of the Shuttle *Columbia* in 2003) underscore the importance of continuing to maintain an appropriate emphasis on the sustainment of existing systems while investing in future launch capability development. The U.S. is more dependent on space systems than it was when the NSTP was released. Consequently, the nation is more vulnerable to disruptions or denial of our ability to access and use space. In light of these significant changes, policymakers could consider whether it would be appropriate for a revised policy to focus more sharply on successfully flying out the remainder of our heritage ELVs while completing the transition to EELV. Drawing from launch system failure reviews, the following themes could be considered in this regard:

- Program Management: ensure adequate and qualified staff, clear lines of authority and responsibility, and an emphasis on mission success and process discipline during heritage system fly-out and transition to EELV;
- Schedule and Resources: ensure balance to avoid adversely impacting mission success;
- Risk Management: ensure program management is aware and informed regarding risks to mission success; and

²⁵ It should be kept in mind that larger-scale threats (e.g., Hurricane Floyd, which missed Cape Canaveral Air Station and Kennedy Space Center, Florida by a narrow margin in September 1999, or an earthquake near Vandenberg USAF Base, California) have the potential to damage or destroy facilities associated with more than one launch system.

²⁶ Statement of the Honorable Peter B. Teets, Under Secretary of the USAF, Before the Commission on the Future of the U.S. Aerospace Industry, 14 May 2002.

²⁷ James Wallace, “Boeing Loses 7 Delta Launches: Air Force Inflicts Penalty Over Theft of Lockheed Documents,” *Seattle Post-Intelligencer* (25 July 2003).

- Systems Engineering: ensure the most important considerations relating to mission success are identified and addressed, including means to build confidence in reliability expectations (e.g., demonstration flights of new vehicles).

Space Launch Capability and Technology Base Maintenance

As discussed above, the NSTP called for the maintenance of “a strong space transportation capability and technology base, including launch systems, infrastructure, and support facilities, to meet the national needs for space transport of personnel and payloads.” This guideline addressed a wide-variety of important issues in one sweeping statement. In the revised policy, these components could be addressed in several shorter and more specific statements. Taking actions to maintain a strong space transportation technology base is particularly important after a decade of industry consolidation and in light of current market conditions, which have made it virtually impossible to attract private investment. A more direct statement that explicitly addresses how to strengthen the space transportation technology base would more clearly communicate its importance as an element of assuring access to space. While there are new manufacturing, processing, and launch facilities in place for both families of EELVs, the facilities associated with the Space Shuttle program are in need of substantial maintenance to support continued safe and reliable operations. The new policy could include a statement that more directly addresses the need to repair and maintain Space Shuttle facilities – although it will likely remain unclear how aggressive these efforts should be until policymakers more fully understand the implications of the Shuttle *Columbia* accident. Finally, the new policy needs to more clearly communicate the importance of maintaining launch ranges as an element of assuring access to space.

Assured Access to ISS

Most of the policy elements that have been addressed above relate more to national security space missions, which rely on ELVs, rather than civil sector missions, which rely on the Space Shuttle. Since 1988, national policy statements have not explicitly referred to the need to provide a backup for the Space Shuttle’s unique capabilities. NASA’s implementation of SLI included development of an automated interim domestic backup to deliver cargo and logistics supplies to ISS. If this aspect of assured access to space is considered to be sufficiently important, particularly in the post-*Columbia* environment, it could be explicitly addressed in the policy.

Foreign Vehicles as Backup to U.S. Systems

For nearly a decade, Lockheed Martin and Boeing have been involved in international partnerships with Russian and Ukrainian launch vehicle manufacturers. Both U.S. companies market commercial launch services worldwide, by offering a family of U.S. and foreign vehicles with overlapping performance capabilities. Thus, they offer their commercial satellite customers backup capabilities for assured access to space using a combination of U.S. and foreign vehicles. The arguments in favor of the use of foreign

launch vehicles by American companies often center around the relatively lower cost of launching on those systems. The primary argument in opposition is that this adversely impacts the market position of domestic providers and calls into question government access to affordable launch services. Both Lockheed Martin and Boeing have seemingly concluded that offering commercial services on foreign launchers makes good business sense. Whether that should transfer to government payloads, however, is another matter altogether – which deserves closer scrutiny. Policymakers could consider the merits of the commercial approach for critical national security payloads in a revised NSTP.

Conclusion

This chapter reviewed relevant space policy, launch studies, and program planning to support the current revision of the NSTP, in accordance with NSPD-15. In particular, it highlighted the features of past U.S. national space policies regarding assured access to space, highlighted findings from launch failures, and evaluated the implications of several approaches to achieving assured access to space for critical U.S. national security, civil, and commercial missions. This review was utilized to generate recommendations for policy language that could be used to address assured access to space in a revised NSTP. Those recommendations include:

- “The Space Shuttle and the EELV fleets will be operated until a well-defined transition can be implemented to proven and operationally available replacement systems.”
- “DoD will work with its industry partners to design, deploy, and maintain two independent and redundant families of U.S. manufactured EELV systems.”
- “DoD will work with its industry partners to develop and maintain EELV launch facilities on both the East and West Coasts.”
- “DoD will take the following actions to emphasize the importance of mission success while flying out existing heritage launch systems and completing the transition to EELV:
 - Program Management: ensure adequate and qualified staff, clear lines of authority and responsibility, and an emphasis on mission success and process discipline during heritage system fly-out and transition to EELV;
 - Schedule and Resources: ensure balance to avoid adversely impacting mission success;
 - Risk Management: ensure program management is aware and informed regarding risks to mission success; and
 - Systems Engineering: ensure the most important considerations relating to mission success are identified and addressed, including means to build confidence in reliability expectations (e.g., demonstration flights of new vehicles).”
- “NASA will pursue Space Shuttle upgrades, in accordance with CAIB recommendations, to address safety, reliability, and obsolescence.

- NASA will implement facility maintenance as required to sustain reliable operation of the Space Shuttle fleet; and
 - NASA will work with DoD to document lessons learned from the transition from heritage ELVs to the EELV fleet to enable effective planning for an eventual transition from the Space Shuttle to a replacement system for human access to space.”
- “DoD will maintain and modernize launch ranges to reduce operating costs and ensure adequate capacity and flexibility to assure access to space.
 - NASA will lead the development of technology roadmaps to define plans for development and demonstration of next-generation range technologies to enable development of space-based and mobile range assets.”
- “NASA will conduct cost and effectiveness trade studies to support a decision by the President or his designee relating to the development of an automated interim domestic backup for the Space Shuttle’s capability to deliver cargo and logistics supplies to the International Space Station.”
- “DoD will seek arrangements with U.S. EELV launch service providers to provide access to foreign launch vehicles as a backup to assure access to space in case of failures or prolonged stand-downs of U.S. launch capabilities.”

Based on our review of relevant space policy, launch studies, and current program planning, we believed that these policy language recommendations could be used to communicate the importance of assured access to space.

CHAPTER THREE: FUTURE SPACE LAUNCH

As the United States moves forward into the 21st century, space activities represent an increasingly important sector from both a national security and economic perspective. Furthermore, the goal of expanding human presence beyond Earth orbit remains a central tenet of the national space program (although it is not currently part of national policy).²⁸ Space launch systems represent the key enabling technology for all human and robotic activities in outer space. Launch vehicles provide the only available capability to lift human crews and payloads into space. Due to the clear importance of these systems, a great deal of focus has been given to continued development of new, advanced space launch capabilities. For that reason, providing guidance for future launch programs has been an essential element of national space transportation policy for decades. While future launch initiatives are undoubtedly related to providing assured access to space (which the Bush administration has indicated will be the focal point of a revised NSTP), the importance of supplying clear guidance for these programs suggests that it merits its own section within a new policy. This chapter presents a brief overview of past launch initiatives aimed at developing a reusable launch vehicle (RLV), which NASA has long seen as the most promising launch system for reducing the costs associated with space transportation activities. Furthermore, the chapter provides a concise overview of the primary future launch initiatives ongoing within NASA and DoD. The ultimate goal of this chapter is to present policy language recommendations that will provide White House support for future launch programs.

Past Launch Vehicle Initiatives

Despite the fact that the nation has been launching rockets for over forty years, space launch remains exceptionally expensive. The average cost of launching a pound of payload into orbit is commonly estimated at \$10,000. The primary element of this price is associated with designing, manufacturing, and operating the vehicle. Another significant component of the cost is the construction and operation of ground infrastructure. A final factor has been the lengthy processing time associated with both ELV and Space Shuttle launch operations. Neither NASA or the Department of Defense have had success during the past several decades in their efforts to dramatically reduce launch expenditures. There are several reasons why space launch systems cost a great deal to operate, which relates to why these attempts have failed.

- There are practical limits to the performance of chemical propulsion rockets. Thus, launch vehicles utilizing these types of engines will not be able to accomplish significant price reduction without achieving revolutionary advances in materials technology to reduce overall vehicle weight.

²⁸ National Aeronautics and Space Administration, *2003 Strategic Plan* (Washington, DC: Government Printing Office, 2003), 17-20.

- An inherent philosophy that requires safe and reliable operations, which is not coupled with an intact abort capability, mandates that a “standing army” of engineers painstakingly inspect launch vehicles to ensure that nothing goes wrong. As a result, this tenet drives cost in the form of civil servant and contractor labor.
- Limited market demand for commercial space ventures at the \$10,000 per pound price point have limited potential “economies of scale” benefits from increased launch rates.
- Conflicting missions and associated vehicle requirements have resulted in poor coordination of technology development programs between NASA and DoD.

There is a long history of government involvement in Reusable Launch Vehicle (RLV) technology development dating back to the late 1950s. During those four and a half decades, NASA and DoD have invested billions of dollars on RLV research. The intended goal of these technology investments was significant reductions in launch costs. It was believed that a highly capable RLV would be able to conduct “multiple routine missions” each year, with relatively quick turnaround through efficient ground operations and robust systems. This would result in significant cost efficiencies through economies of scale, which would provide budgetary benefits for the American space program. The following bullets provide an overview of the major RLV development programs undertaken during this period and the level of federal investment. This is intended to provide an idea of the scope of the federal investment (in then-year dollars) on these types of programs – none of which led to an operational, fully reusable launch vehicle capable of dramatically decreasing space transportation costs.

PROGRAM	INVESTMENT	OVERVIEW
X-20 Dynasoar	~\$400 million	Initiated in 1957 by the United States Air Force (USAF) to develop a reusable-piloted glider, with a small payload capacity. Cancelled in 1963 due to the complexity of the technology, rising costs, and competing budget priorities.
Project START	~\$1 billion	Initiated in 1963 by USAF to pursue manned spaceplane concepts. Cancelled in 1975 after a twelve-year test flight program, which conducted more than 80 test flights and compiled a wealth of information on lifting body design.
Space Shuttle	\$11.4 billion initial development	Initiated in 1972 by NASA to provide human access to space. This “refurbishable launch vehicle” has conducted over one hundred flights, but remains extremely expensive to operate (\$3.8 billion annually).
X-30 National Aerospace Plane	\$3-5 billion	Initiated in the mid-1980s by DoD to develop a hydrogen-powered, single-stage-to-orbit air/spacecraft capable of horizontal takeoff and landing, operating at orbital speeds (Mach 25), and sustained hypersonic cruise within the atmosphere. Cancelled in the early 1990s prior to the production of a test flight vehicle.
Delta Clipper Flight Experiment	\$50 million	Initiated in 1991 by the Ballistic Missile Defense Organization to develop a reusable launch system to support the organization’s multiple launch requirements. Terminated in 1996 following destruction of DC-XA vehicle during a test flight.
X-33 Advanced Technology Demonstrator	\$1 billion	Initiated in 1996 by NASA to reduce business and technical risks, which would enable privately financed development and operation of a low cost next generation space transportation system. Cancelled in 2001 due to significant technical problems and budgetary considerations.
X-34 Technology Testbed Demonstrator	\$219 million	Initiated in 1996 by NASA to validate key reusable launch vehicle operations and technologies. Cancelled in 2001 due to budgetary considerations.
X-37 Advanced Technology Flight Demonstrator	\$301 million	Initiated in 1998 by NASA to test technologies for both the orbital and reentry phases of flight.

Table 1: Federal Investment in RLV Programs

In sum, the nation has spent over \$8 billion (in-then year dollars) over the past 45 years on RLV technology development programs.²⁹ This represents a sizable federal investment with few accomplishments with regard to development of an operational flight vehicle capable of replacing the Space Shuttle, dramatically reducing launch costs, or providing safer and more reliable access to space.³⁰

As discussed in Chapter One, the NSTP provided a significant bifurcation of responsibilities for development of future space launch systems. DoD was made the lead agency for improvement and evolution of the U.S. expendable launch vehicle (ELV) fleet, including appropriate technology development. The Evolved Expendable Launch Vehicle (EELV) was the program selected by the USAF to implement the policy. This program has largely been a success, with both the Atlas V and Delta IV launch vehicle families achieving initial launches in the late summer and fall of 2002. NASA, on the other hand, was made the lead agency for technology development and demonstration for next generation reusable space launch systems, such as the single-stage-to-orbit (SSTO) concept.³¹ The X-33 Advanced Technology Demonstrator program was selected by the space agency to implement the policy. As described above, that program failed to field an actual demonstration vehicle, or inform “an end of decade” decision regarding the development of an operational next-generation reusable launch system. Its most important contribution was to prove the SSTO concept unworkable, which argues for its elimination from the revised policy.³²

Future Space Launch Initiatives

Due to the continued high cost of space transportation systems, the American space program has continued efforts to develop launch vehicles with advanced technologies in the aftermath of the failure of the X-33 and X-34 programs. The two major elements of this effort have been NASA’s Space Launch Initiative (SLI), an effort to build “safe, reliable, cost-effective space transportation technology;³³ and DoD’s National Aerospace Initiative (NAI), “an interagency efficiency drive that could see hypersonic weapons technology evolving into air-breathing first stages for space launch vehicles.”³⁴

²⁹ This figure includes \$1.5 billion that has been invested thus far in the 2nd Generation Reusable Launch Vehicle Program, but excludes development of the Space Shuttle.

³⁰ William Burroughs, *This New Ocean: The Story of the First Space Age* (New York: Random House, 1998), p. 523; “X-33, X-34 left behind in NASA Space Launch Initiative,” *Spaceflight Now* (1 March 2001); “NASA Terminates Funding for X-33 / X-34 Programs,” *Space and Tech* (1 March 2001); National Aeronautics and Space Administration, X-37 Fact Sheet, released 1 March 2001; National Aeronautics and Space Administration, Office of the Chief Financial Officer; National Aeronautics and Space Administration, Space Launch Initiative Program Office, Marshall Spaceflight Center.

³¹ While the National Space Transportation Policy of 1994 called for cooperation between NASA and DoD on RLV technologies, it was not strongly advocated within the document.

³² White House Office of Science Technology Policy, National Space Transportation Policy, 5 August 1994.

³³ NASA Marshall Space Flight Center, “The Space Launch Initiative: Technology to Pioneer the Space Frontier,” April 2002 (FS-2002-04-87-MSFC).

³⁴ Frank Morring, “National Aerospace Initiative’ Pushes Dual-Use Technology,” *Aviation Week and Space Technology* (20 May 2002).

Space Launch Initiative

In February 2001, NASA launched SLI in the wake of the failure of the X-33 program – an effort to fly a half-scale flight demonstrator designed to validate advanced technologies intended to dramatically reduce the cost of putting a pound of payload into space (from \$10,000 to \$1,000). SLI, also known as the 2nd Generation RLV program, was designed as a \$4.8 billion, six-year effort that incorporates three strategic goals:

- Invest in technology development and other activities needed to enable a full-scale development decision by 2006 and operations by early next decade of a space transportation system that will be safer, more reliable and less expensive than today's system.
- Implement a coordinated approach to develop flexible, commercially produced, reusable launch vehicles. This approach would ensure that NASA unique hardware, developed by and for NASA unique missions (such as crew transport and planetary exploration) is compatible with commercial capabilities.
- Purchase cargo re-supply services for the International Space Station (using commercial launch vehicles) to serve as backup for primary vehicles such as the U.S. Space Shuttle and international vehicles such as the Russian Progress rocket.

SLI was meant to facilitate the expansion of commercial space markets, Earth and space science investigations, and human and robotic exploration of the solar system. The program was part of an overall trend within the federal government to competitively source governmental activities where practicable. Within the space transportation arena, NASA has been moving toward the transfer of launch vehicle operations to the private sector. Within this context, SLI aimed to reduce risk and consequently increase the willingness of the aerospace industry to invest capital in vehicle development.³⁵ The SLI program was intended to examine technologies in eight different areas.

³⁵ NASA Marshall Space Flight Center, "The Space Launch Initiative: Technology to Pioneer the Space Frontier," April 2002 (FS-2002-04-87-MSFC).

TECHNOLOGY	OVERVIEW
Airframe Systems	focus on advanced airframe design and integration methods to improve reliability and reduce design cycle time; robust, low-cost, low-maintenance structures, tanks, thermal protection systems and thermal structures; and, aerodynamic and aerothermodynamic assessments which yield higher-fidelity information early in the design process.
Flight Demonstrations	focus on flight-testing of selected hardware and software technologies (avionics, guidance and navigation systems, thermal protection systems, fuel tanks, integrated vehicle health management systems, autonomous flight operations and crew escape systems) in a relevant ascent, orbit, and reentry environment to reduce the risk of future launch system development.
Flight Mechanics	focus on development of adaptive software that will allow spacecraft (rather than the pilots) to solve problems, and advances in automatic rendezvous and docking systems.
Integrated Vehicle Health Management	focus on highly integrated systems that could include advanced sensors, model-based reasoning systems, diagnostic and prognostic software, and intelligent software managers and planners. These technologies will be used to collect, process, and integrate information about the vehicle's health enabling informed decision-making and logistics management.
NASA Unique Systems	focus on a wide variety of technologies including crew escape systems, environmental control systems, cockpit systems, mission planning, flight operations, crew return vehicles, crew transfer vehicles, and non-crew transfer vehicles.
Operations	focus on advanced checkout & control systems, separation systems, ground to flight interfaces, propellant densification, and fluid transfer technologies.
Propulsion	focus on specific Earth-to-orbit technologies including rocket, augmented rocket, and combined-cycle propulsion (which may include air or magnetic launch assistance).
Vehicle Subsystems	focus on advanced technologies in actuators, power and avionics.

Table 2: SLI Technology Development

SLI was to be the first step toward identifying technologies relevant to the creation of a safer, more cost-effective launch system. As originally conceived, the initiative was intended to lead to a fully operational reusable launch system early in the next decade, capable of placing one pound of payload into orbit for \$1,000. The hope was that this would set the agency on a path that would result in a further decrease in launch costs by a factor of ten (\$100 per pound) by 2025. The belief was that this type of price reduction would enable the development of a robust commercial space market, which will have the added bonus of offsetting government expenditures for space launch.^{36/37}

Challenges Facing SLI and Implications for the NSTP Review

In September 2002, the General Accounting Office (GAO) released a report entitled *Space Transportation: Challenges Facing NASA's Space Launch Initiative*. The report, commissioned at the request of House Subcommittee on Space and Aeronautics, found that the space agency needed to address several major problems with the program before a critical Systems Requirements Review (SRR) in November 2002. GAO suggested that NASA would be unable to proceed with the SRR without first completing a reassessment of its overall space transportation plans. "In doing so," the report stated, "[NASA] must decide whether it should continue pursuing the development of second-generation vehicles as planned, pursue alternative ways to develop the second-generation in order to more quickly replace the space shuttle, or postpone these efforts altogether until there is a major breakthrough in technology that could

³⁶ NASA Marshall Space Flight Center, "The Space Launch Initiative: Technology Summary," August 2002 (FS-2001-08-198-MSFC to FS-2001-08-205-MSFC).

³⁷ Although outside the scope of this paper, it is essential that the next NSTP consider economic factors and policy to help ensure the U.S. captures this market, and therefore receives a return on its substantial investment in this technology.

vastly improve performance and reduce costs.”³⁸ In many respects, this issue represents the central question for any revision of national space transportation policy. Based on that idea, suggestions for the policy include:

- The future space transportation section could provide policy direction with regard to the adoption of a long-term space transportation strategy.
 - This strategy would include the establishment of a process for making informed decisions that will meet future civil space program mission requirements without presupposing a technical answer.
 - At minimum, the section could direct the establishment of a formal procedural framework for development of advanced transportation technologies.
 - At maximum, the policy could mandate that SLI proceed with 2nd generation vehicle development, alter its course in favor of a 2nd generation concept based on a Crew-Transfer-Return-Vehicle (CTRV), or omit 2nd generation technology development in favor of more revolutionary 3rd generation spacecraft technologies.
 - A variation of this would direct NASA to develop a relatively inexpensive CTRV and redirect funding to advanced 3rd generation propulsion
- Closely linked to this issue is the proper level of investment in Shuttle upgrades. The policy could make clear whether NASA is to fund only safety and obsolescence upgrades (including those within the CAIB report), or should also move forward with performance upgrades.
 - The planned lifetime of the Shuttle will influence this decision. If the policy requires NASA to move from the Shuttle to another vehicle as soon as possible, safety and obsolescence upgrades may suffice to fly the system until that transition. If the policy remains to fly the system until 2020 or beyond, then considerable performance upgrades may be necessary.
 - A decision to go forward with performance upgrades for the Shuttle would represent a significant federal investment, which could otherwise be used for 2nd or 3rd generation technology and vehicle development. If one of the primary goals of the NSTP is to promote future space transportation developments, NASA could be directed to limit performance upgrades.

GAO also suggested that NASA needs to make key decisions regarding the essential crew complement for the International Space Station. This decision would “have a dramatic impact on NASA’s requirements for

³⁸ United States General Accounting Office, Report to the Subcommittee on Space and Aeronautics, Committee on Science, House of Representatives, “Space Transportation: Challenges Facing NASA’s Space Launch Initiative,” September 2002 (GAO-02-1020).

a second-generation vehicle.”³⁹ While setting policy regarding ISS crew size is beyond the scope of the NSTP, language could be included which would provide flexibility when deciding on the best course for ISS from financial, scientific, and political perspectives. Based on that idea, suggestions for the policy include:

- The future space launch section could include implicit policy direction stating that any future systems be capable of returning a set number of astronauts (between 4 and 7) from ISS in an emergency situation.
 - This may implicitly suggest that the proper near-term direction for space launch is a CTRV. It is unclear whether there is another 2nd or 3rd generation system architecture that could provide for crew return.
- The policy could direct NASA to continue using the Russian Soyuz capsule for crew return and mandate that efforts be made to increase the number of capsules acquired from 2 to 4 annually, which would provide crew escape for up to six astronauts.
 - This could eliminate the need for a CTRV.
 - This would increase reliance on foreign vehicle providers.
- The policy could eliminate the NASA requirement for a crew escape capability, thereby accepting the resultant risks.
 - This would permit redirecting CTRV funding toward development of new systems, but would be politically contentious.

Finally, GAO suggested that NASA should decide whether to cooperate with DoD on future RLV technology development. The report found that “NASA and DoD will share many of the same objectives for the vehicle, but there are significant differences in priorities and requirements.”⁴⁰ Substantial efficiencies could be gained from NASA-DoD RLV technology partnerships. Therefore, a revised NSTP could direct NASA and DoD to analyze potential efficiencies. Based on that idea, suggestions for the policy include:

- In the future space launch section, a revised NSTP could direct that NASA and DoD cooperate on technology efforts.
 - This statement could include direction to cooperate with other agencies where appropriate.
 - This statement could direct the two agencies to cooperate on technology demonstrators. Reasons not to include this in the policy are that:

³⁹ Ibid.

⁴⁰ Ibid.

- It presupposes a benefit from flight demonstrators, despite the historically high cost of these vehicles.
- It is unclear that the NASA and DoD missions mesh well enough to get valuable data from a joint demonstrator program.

GAO made a persuasive argument that until SLI (as well as the Shuttle and Station) selects a long-term strategy for future space launch systems, it will be difficult to implement needed management and accounting reforms. Without these in place, there is a very real risk that the program will face continued budgetary and technical problems. This problem is even more in the forefront after the release of the CAIB report and the new NASA implementation plan for Shuttle return to flight.⁴¹

On 22 October 2002, in response to the GAO report, NASA indefinitely postponed the SRR. The agency announced that it would “reschedule the review when the agency completes its assessment of its Integrated Space Transportation Plan, ascertains the role of the Department of Defense in the SLI, determines the future requirements of the International Space Station and firms up the agency's future space transportation needs.”⁴² On 13 November, NASA revealed the results of its Integrated Space Transportation Plan (ISTP).⁴³ This new approach to meeting future space launch needs included three primary features: Space Shuttle, making investments to extend the safe operations of the system to 2020; Orbital Space Plane (OSP), providing a crew transfer capability, as early as possible, to ensure access to and from the ISS; and Next Generation Launch Technology Program, funding developments in areas such as propulsion, structures, and operations for a next generation RLV. There are significant implications of this realignment for a revised NSTP, particularly from a future space launch perspective. The revised policy could provide the agency with strong policy direction regarding the administration's priorities for meeting future space launch needs, particularly if they don't match those announced in the new ISTP and revised SLI program.

National Aerospace Initiative

In 2002, the DoD introduced the National Aerospace Initiative (NAI), a time-phased science and technology effort to research potential military roles for RLVs. The proposed \$2.6 billion, 7-year program is part of the department's larger Technology Transformation Initiative. It is intended to pursue the following stepping-stone approach to hypersonics technology development:

- Near-Term: supersonic/hypersonic missiles (time-critical targets)
- Mid-Term: hypersonic cruiser (global reach/attack)

⁴¹ Ibid.

⁴² Brian Berger, “NASA Postpones Next Phase of Space Launch Initiative,” *Space.com* (22 October 2002).

⁴³ For further information regarding NASA's Integrated Space Transportation Plan, visit www.spacetransportation.com on the Internet.

- Far-Term: RLV (affordable, timely access to space)

The initiative is an interagency effort managed by the Director, Defense Research and Engineering (DDR&E) within DoD. NASA Administrator Sean O’Keefe has enthusiastically supported the undertaking, and encouraged the space agency’s participation in a 120-day study of potential areas for technological cooperation.⁴⁴ The DoD goal is to reach across the government for technology that can be used for military purposes. At the same time, NASA and other agencies would be able to satisfy their space-related requirements without duplicating efforts (and investments) in the federal government. The NAI is focused on advanced hypersonics, access to space, and space technology. The DDR&E’s approach is to pull together an inventory of available technologies and ongoing programs to expand these areas.⁴⁵

The near-term goal of NAI is to foster the development of hypersonic missiles that can hit moving targets before they get away, while allowing military leaders to locate launch platforms at protected sites (further from the battlefield). However, this near-term goal may enable the development of Mach 12, air-breathing propulsion systems that could be used as the first stage of a two-stage-to-orbit (TSTO) launch vehicle. Ron Sega, the current DDR&E, has stated that the goal of the program is to push hypersonic technology by “a Mach number a year.” This would result in the availability of a Mach 12 capability by 2012. This would potentially pave the way for a Mach 8-12 RLV within the 2016-2025 timeframe, which would be capable of providing responsive, flexible access to space.

The DDR&E has not yet determined whether NAI would develop a rocket-powered or air-breathing launch vehicle, although the program is clearly oriented toward the latter. The intended common attributes of this system would include: “aircraft-like” operations; reliability and maintainability; responsiveness; alert capability; rapid turnaround time; autonomous operations; minimal ground crew; low operations cost; minimal facilities; and continental U.S. launch and recovery functionality. The NAI roadmap calls for three phases of space access development, building on a foundation of experience that includes the Space Shuttle, Delta Clipper, X-33, and SLI Program technology advances.

⁴⁴ The study concluded that that the United States Air Force and NASA should assess potential opportunities for building a joint Reusable Launch Vehicle (RLV) demonstrator.

⁴⁵ Ron Sega, Director, Defense Research and Engineering, National Aeronautics Initiative Program Briefing, presented at FAA COMSTAC meeting on 31 October 2002.

	PHASE I – 2008	PHASE II – 2015	PHASE III – 2025
Turnaround	Sustained 7 Day	Sustained 1 Day	Sustained 12 Hour
Airframe	250 Sortie	500 Sortie	1,000 Sortie
Propulsion System	100 Sortie	250 Sortie	500 Sortie
Marginal Cost/Sortie	\$10 million	\$5 million	\$1 million
Reliability (loss rate)	1 in 1,000	1 in 2,000	1 in 5,000
Weather	Weather Sensitive	Weather Tolerant	Most Weather
Weight	Low Weight	Reduced Weight (10%)	Reduced Weight – (15%)
Payload Fraction	8%	16%	24%

Table 3: NAI Roadmap

If officially adopted by DoD, NAI represents an incredibly aggressive and confident leap into hypersonics and RLV research and development. It is unclear at this juncture, however, whether the plan will be fully implemented. Regardless, the initiative provides a compelling overview of DoD’s requirements for future space transportation systems.⁴⁶

Implications for the NSTP Review

In general, because they have different mission requirements, DoD and NASA have different RLV needs. DoD needs a relatively small payload, launch-on-demand capability. NASA (and the commercial sector) is more interested in large payload capacity and increased safety for human missions. Regardless, DoD has seemingly embarked on a robust technology demonstration program that would serve military and intelligence requirements, but may also provide important technologies for meeting civil and commercial requirements. Thus, a revised NSTP could provide DoD with firm policy direction to support this outcome. The policy could also direct DoD and NASA to cooperate on RLV technology development and encourage DoD research into air-breathing propulsion systems capable of acting as a first stage of a combined-cycle RLV. While this is a significant departure from the NSTP, it may increase the chances that both military and civil requirements for RLVs will be met within the next twenty years by bringing more funding and engineering expertise to this technical area.

Conclusion

This chapter reviewed relevant space policy, launch studies, and program planning to support a potential revision of NSTP, in accordance with NSPD-15. In particular, it highlighted the features of existing U.S. space launch initiatives and reviewed their implications for the NSTP review. This review was utilized to generate recommendations for policy language that could be used to address future space launch options in a revised NSTP. Those recommendations include:

⁴⁶ Ibid. This assumes, of course, that the EELV program will continue to provide the military and intelligence sectors with medium- and heavy-lift capability.

- “The Department of Defense and the National Aeronautics and Space Administration will cooperate in technology development efforts aimed at dramatically reducing the cost of space launch systems.
 - These cooperative efforts will further seek to improve the safety, responsiveness, and reliability of space launch systems for national security, civil, and commercial purposes.
 - The National Aeronautics and Space Administration shall cooperate with other government agencies where appropriate.”
- “The National Aeronautics and Space Administration will establish a formal procedural framework for developing advanced future space launch technologies, which will be utilized to annually update a strategic plan for achieving dramatic cost reductions and improved safety, responsiveness, and reliability of space launch systems.”
- “The National Aeronautics and Space Administration will develop a Crew-Transfer-Return-Vehicle capable of being launched aboard an Evolved Expendable Launch Vehicle, to enable an early transition from the Space Shuttle.
 - This vehicle shall be capable of returning a crew of between four and seven astronauts from the International Space Station in an emergency situation.
 - Until a Crew-Transfer-Return-Vehicle is available, the National Aeronautics and Space Administration will investigate opportunities for utilizing additional Soyuz spacecraft to provide a six crew escape capability for the International Space Station.”
- “The National Aeronautics and Space Administration will conduct advanced propulsion research focused on 3rd generation concepts.
 - The Department of Defense will conduct hypersonic and air-breathing propulsion system research that could be used as the first stage of a next-generation launch vehicle and identify synergistic opportunities with NASA and the commercial sector.”

Based on our review of relevant space policy, launch studies, and current program planning, we believed that these policy language recommendations could be used to communicate the importance of addressing future space transportation requirements within a revised policy.

CHAPTER FOUR: IN-SPACE TRANSPORTATION

As policymakers begin to investigate program alternatives for the American space program after completing construction of the International Space Station (ISS), mission planners inside the space agency are increasingly finding that advanced propulsion technologies (and nuclear energy in particular) are the key enablers to aggressive exploration of the solar system. In an interview published in *Space News* on 9 September 2002, National Aeronautics and Space Administration (NASA) Administrator Sean O’Keefe made it very clear that he favors assertive development of in-space transportation technologies. “We are in the Age of Sail right now in space exploration and we are aspiring to the Age of Steam,” O’Keefe said. “Everything I am pressing in terms of the agency’s agenda right now is to overcome that and arrive at that Age of Steam.” The NASA administrator has unmistakably placed the agency on a firm course seeking to dramatically improve technologies for in-space transportation. Given the envisioned importance of new propulsion technologies for space transportation, it is important to address these important issues in a revised NSTP.^{47/48} This chapter presents a brief overview of past in-space transportation initiatives and provides concise summaries of current programs. The ultimate goal of this chapter is to use this historical analysis, combined with the overview of ongoing efforts, to provide policymakers with policy language recommendations to appropriately address in-space transportation in a revised NSTP.

On spacecraft ranging from orbiting satellites to deep space probes to the Space Shuttle, propulsion systems account for a major portion of total mass. Thus, reducing the size and increasing the performance of these systems would have a significant impact on breaking the barriers to affordable spacecraft. Traditionally, efforts aimed at reducing costs have focused squarely on access to space. More efficient and robust in-space systems, however, offer the government (and commercial customers) with another avenue to cut the cost of space operations. This result will allow NASA to more insistently chart a course for expanded robotic and human exploration of the solar system, which is apparently the strategic direction that NASA would like to follow. In an interview published in *Space.com* on 10 October 2002, NASA Deputy Administrator Frederick Gregory expressed the agency’s agenda as follows: “I think we’ve spent a lot of time in low Earth orbit (LEO). I think all of our focus has been that way. I don’t see that as the future.” The deputy administrator suggested that it was time for NASA to break out of its LEO isolation for human exploration. He argued that the agency needs to focus on research-driven exploration of the

⁴⁷ Administrator O’Keefe’s answers to questions posed by Space News highlight the importance of in-space transportation on his agenda: (Q) Launch applies to all three of the goals you [have laid out for the agency]. Do you have an approach in mind for space launch?; (A) We need breakthroughs in power-generation and in-space propulsion. If we get to the point where we shave a minute off an eight-minute trip to low Earth orbit, so what? It doesn’t do us any damn good if we are still in a coast mode once we get there. The single most important effort we are after this year and the years to follow is to push for power generation and propulsion programs like the Nuclear Systems Initiative. It has the potential to dramatically reduce the time it takes to traverse the solar system; (Q) Do you view that as a bigger problem than getting from Earth to orbit, even considering the enormous cost of that first step?; (A) You bet...; (Q) Do you plan more big changes for space science or will you focus on implementing the New Frontiers program and Nuclear Systems Initiative?; (A) The focus will very much be on making sure those work and, to the extent possible, looking to more aggressively implement them. We are looking seriously at some alternatives to step up those initiatives and introduce some of those applications sooner.

solar system, and must make investment decisions in technology areas that enable that vision. His overall message to the space agency was to think boldly again about technology options for improving capabilities for expanded exploration beyond LEO.⁴⁹

Historical Perspective

At the beginning of the 20th century, leading American rocketry pioneer Robert Goddard speculated that solar and nuclear propulsion techniques would be the key to long-range exploration of the solar system. In 1907, he wrote in his personal notebooks that:

It is evident, from the calculations made regarding the use of solar energy in space, that the most extreme speeds will be produced by solar, rather than by chemical energy.... If it is possible to obtain infra-atomic energy, the matter of transportation would be comparatively simple, and a large body could be sent from the solar system.... Further, atomic disintegration may open the way for the creation of what might be called artificial atoms, in which energy might be stored by many high-speed particles. This tremendous amount of energy could be liberated when these artificial atoms were broken up, or the particles were removed gradually.⁵⁰

In 1912, Frenchman Robert Esnault-Pelterie was the first researcher to publish a paper on the use of atomic energy for space travel. In the article, he argued that nuclear propulsion would be instrumental for reaching the Moon and other celestial bodies.⁵¹ Goddard and Esnault-Pelterie's contemporaries, visionaries like Konstantin Tsiolkovsky and Hermann Oberth, however, disparaged the practicality of nuclear propulsion and concentrated on chemical rockets. As a result, advanced concepts did not make it into the mainstream of space transportation research for several decades – particularly after it became clear that chemical propulsion would suffice for trips to Earth orbit and the Moon. While early developmental programs clearly concentrated on chemical rocket engines, nuclear concepts slowly gained support. In the post-World War II period, several studies were undertaken to investigate opportunities to combine recently developed nuclear and rocket technologies – including a 1946 Douglas Aircraft study of a fission powered rocket. In the coming decades, while still remaining largely on the periphery of space transportation

⁴⁸ "New Chief Hopes to Guide NASA to Its Age of Steam," *Space News* (9 September 2002).

⁴⁹ Leonard David, "NASA's Frederick Gregory: Agency's All Clear to Think Boldly Once Again," *Space.com* (10 October 2002).

⁵⁰ Robert Goddard, "The Ultimate in Jet Propulsion," unpublished manuscript, 1943, in *The Papers of Robert H. Goddard*, (New York, McGraw-Hill, 1970).

⁵¹ Lise Blosset, "Robert Esnault-Pelterie: Space Pioneer," in *First Steps Toward Space*, ed. Frederick Durant (Washington, Smithsonian Institution Press, 1974).

research and development, several large government programs were initiated to examine advanced and nuclear in-space propulsion.⁵²

Project Rover/NERVA

In 1954, the Department of Defense's (DoD) Scientific Advisory Board met to consider the application of nuclear energy to missile propulsion. In its report, the committee observed that the nation had experienced a six-year hiatus in the study of nuclear propulsion. As a result, they recommended that an experimental program be launched because "another 6 years of no progress in this area would seem to be unfortunate...."⁵³ The following year, the United States initiated a nuclear rocket program called Project Rover. The goal of the program was to build full-scale operating versions of fission-driven rocket reactors. In 1961, Project Rover was transformed into the Nuclear Engines for Rocket Vehicle Applications (NERVA) program when NASA established the Space Nuclear Propulsion Office (SNPO). SNPO was managed as a joint office between the Atomic Energy Commission (AEC) and NASA – the former had responsibility for development of nuclear power reactors, while the latter was in charge of the vehicles that would use the engines. Under the program, twelve reactors were tested; each with adjustments in fuel and control systems that offered enhanced power and operational flexibility. The program provided significant technical achievements, developing a high-thrust nuclear thermal propulsion system – the last engine of the series (the XE') was test operated for a total of three hours and 48 minutes, with 11 minutes at full power. Two years after this testing, however, the program was terminated. In retrospect, the program was likely cancelled because by the time the technology reached a level of maturity that warranted development of an operational flight test vehicle, the nation's political leadership had lost interest in spending huge sums of money on space travel. Between 1955 and 1972, the federal government invested approximately \$1.4 billion (in then year dollars) on nuclear rocket development.⁵⁴

Project Orion

Project Orion was a space transportation concept intended to provide propulsion by exploding atomic bombs roughly two hundred feet behind a spacecraft. While on its surface this idea seems ridiculous, several well-known physicists worked on the program and were certain that the idea was feasible. The concept was an attempt to get around the inability of existing technology to construct a practical nuclear combustion chamber for space operations. In 1955, Stanislaw Ulam and Cornelius Everett produced a classified paper that introduced a design that would remove the combustion chamber completely. In its place, bombs would be ejected behind the spacecraft, followed by solid-propellant disks. The atomic

⁵² Federation of American Scientists, "Thermal Nuclear Propulsion," available from www.fas.org/nuke/space/index.html; Internet; accessed 6 November 2002.

⁵³ Eugene Emme, *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space 1915-1960* (Washington, DC: National Aeronautics and Space Administration, 1961).

detonation would vaporize the disks, and the resulting plasma would impinge upon a pusher plate attached to the spacecraft – the system would not be temperature- or power-limited.⁵⁵

Project Orion began as a private operation conducted by General Atomics in San Diego, California. The intellectual leader behind the undertaking was Theodore Taylor (a veteran of the Los Alamos weapons programs) and Freeman Dyson (a theoretical physicist at the Institute for Advanced Study in Princeton). In July 1958, DoD's Advanced Research Projects Agency (ARPA) agreed to supply initial government funding for the program of \$1 million annually. However, after only two years, ARPA was forced to end the relationship because they could find no immediate military applications for the system. In the subsequent five years, Taylor and Dyson kept the project alive at General Atomics and attempted to get NASA to back the program. Werner von Braun actually became a significant supporter of the concept. Regardless, the idea never caught on with senior NASA leadership and was terminated in 1965.⁵⁶

SDI and SEI

Following the demise of NERVA in 1972, and while NASA was developing the Space Shuttle system, no noteworthy developmental work was done in the areas of advanced in-space or nuclear propulsion. In March 1983, after President Reagan's announcement of the Strategic Defense Initiative (SDI) in a nationally televised address, there was some indication that SDI would require space nuclear reactors to provide electrical energy for the proposed anti-ballistic missile systems. As a result, the Strategic Defense Initiative Office (SDIO) created the Multi-Megawatt (MMW) space power program, which received significant funding through the end of the 1980s. However, early interest in space nuclear power sources was quickly moderated by unclear requirements and the availability of a number of more appealing alternatives. By the early 1990s, the MMW effort was discontinued.⁵⁷

There was another burst of interest in nuclear propulsion systems in 1989, when President George Bush announced the Space Exploration Initiative (SEI) – a program aimed at a permanent return to the Moon and human missions to Mars early in the 21st century. In the *90-Day Study*, a blueprint for implementing SEI, NASA indicated that advanced Nuclear Thermal Rocket Propulsion could be employed to dramatically decrease the trip time to Mars. In 1991, the *Synthesis Group Report* recommended a “nuclear rich” alternative to reaching the red planet, arguing that utilizing atomic technology would make for a cheaper, faster, and safer mission profile. Despite this early enthusiasm, however, the administration was never able to gain substantial support for SEI within the U.S. Congress. As a result, for the subsequent

⁵⁴ “US Nuclear Rocket Programs,” *Atomic Energy Insights* (September 1995); Federation of American Scientists, “Thermal Nuclear Propulsion,” available from www.fas.org/nuke/space/index.html; Internet; accessed 6 November 2002.

⁵⁵ Michael Flora, “Project Orion: It's Life, Death, and Possible Rebirth,” available from www.islandone.org/Propulsion/ProjectOrion.html; Internet; accessed 6 November 2002.

⁵⁶ *Ibid.*

decade no important research was conducted within NASA with regard to nuclear propulsion. While small levels of funding were appropriated for the development of advanced in-space propulsion concepts, there has not been any major developmental program during this time period.⁵⁸

NASA Exploration Team

In 1999, NASA charted the Decadal Planning Team (DPT) to generate an integrated strategy for science-driven (as opposed to destination-driven) technology development to enable space exploration. Renamed the NASA Exploration Team (NExT), the organization coordinates efforts across the space agency's ten field centers. The more than fifty senior scientists and engineers participating in NExT are focused on revolutionary (not evolutionary) ideas for future voyages of discovery. The goal of the team is to develop alternative scenarios, architectures, mission concepts, technology roadmaps, and investment priorities to enable the realization of NASA's mission – *to improve life here, to extend life to there, to find life beyond*. The undertaking is centered on three different programs: In-Space Propulsion, Project Prometheus, and the Space Radiation Program. The first (and perhaps most important) challenge to enable the full implementation of the NExT strategy is the development of highly advanced space transportation systems (both Earth-to-orbit and in-space) that are safe, fast, and efficient. The need for in-space transportation, "beyond current chemical approaches, facilitates the steps beyond LEO. The capability to move mass quickly through space toward a destination will decrease travel times and expose astronauts and cargo to less of the hazards of deep space."⁵⁹

Advanced In-Space Propulsion

NASA's in-space transportation investment area is seeking to reduce the cost of traversing near-Earth and interplanetary space, while also reducing travel time for planetary missions. NASA believes that the achievement of this objective will enable greater development of space for scientific, government, and commercial purposes. "In-space transportation systems of the future," NASA argues, "will feature simpler, lighter weight, low-maintenance vehicles that may use alternative energy sources. From solar propulsion to antimatter, [NASA] is experimenting with innovative technologies that could transform science fiction into scientific fact." To organize its efforts in this area, the space agency has established a three-tiered strategy for the future – each with its own challenges and intended outcomes.

⁵⁷ Federation of American Scientists, "Thermal Nuclear Propulsion."

⁵⁸ Ibid.

⁵⁹ Gary Martin and Lisa Guerra, "NASA Exploration Team: Recent Accomplishments," National Aeronautics and Space Administration (2002).

THRUST	CHALLENGES	OUTCOMES
Earth Orbital	Advance existing propulsion technologies for higher performance and reliability.	A commercially operated “Highway in Space” that provides highly reliable, safe, and low-cost access to space.
	Develop new upper stage propulsion sources that are less than half the weight of current chemical systems and do not use toxic propellants.	An order of magnitude reduction in interorbital transfer costs within 15 years.
	Identify viable reusable orbit transfer concepts.	Reduction in travel time for planetary missions by a factor of two within 15 years.
Planetary Transfer	Reduce the propulsion system dry mass by 50 percent while improving system longevity by a factor of two.	Enhanced scientific discovery and exploration through missions conducted with greater capability and in significantly shorter time spans.
	Provide a compact, cheap, and reliable alternative to ion engines.	Reduction in travel time for planetary missions by an additional order of magnitude within 25 years.
	Advance concepts for interplanetary transportation such as high power electric thrusters and lightweight solar sails.	
	Advance core planetary capture technologies in aerocapture, and cryo-fluid management.	
	Reduce the mass of small chemical propulsion systems by a factor of three.	Exploration through newly enabled interstellar missions.
Interstellar Transfer	Determine advanced propulsion concepts for interstellar probe precursor missions.	
	Advance laser-driven sail, fusion propulsion, and anti-matter driven fission/fusion propulsion.	

Table 4: Advanced In-Space Propulsion Strategic Thrusts

These goals are designed to make possible a new generation of space science missions, as well as human exploration beyond Earth orbit. The immediate objective of NASA’s Advanced Space Transportation Program is to mature, test, and fly advanced in-space propulsion technologies that will achieve the goals stated above. The following provides a brief overview of the research efforts already underway.⁶⁰

Electric Propulsion

Electric propulsion technologies utilize electrical energy obtained from solar or nuclear sources to accelerate a propellant – this propellant is subsequently converted to thrust. Electric propulsion is capable of achieving extremely high exhaust velocities, therefore representing a lightweight alternative to chemical fuels and enabling spacecraft to travel faster and carry larger payloads. Physicist Eric Lerner discussed the relative advantages of electric propulsion in a recent article in *The Industrial Physicist*, saying:

The key limitation of chemical rockets, which electric propulsion can overcome, is that their exhaust velocity is relatively low, around 2 km/s and never more than 3.5 km/s. Because achieving Earth orbit requires a velocity change of 8 km/s, a rocket must carry far more propellant than payload... electric propulsion can alleviate these problems by providing far higher exhaust velocities and, thus, greatly reducing the required propellant mass... [Deep Space 1 produced] exhaust velocities of 100 km/s.

⁶⁰ NASA Aerospace Technology Enterprise, “In-Space Transportation: Extend Our Reach in Space,” available from www.aerospace.nasa.gov/goals/eartho.htm; Internet; accessed 4 October 2002.

Thus, electric propulsion would theoretically offer cheaper, faster, and more efficient engines for deep space probes – and potentially for human exploration. There are three primary electric propulsion technologies that are being considered by government and non-government scientists and engineers.⁶¹

Ion propulsion represents one of the most promising electric propulsion technologies, which is ten times more efficient than chemical systems. Ion propulsion involves electrically charging a gas (e.g. xenon), accelerating it to speeds of about 30 km/second, and emitting it as exhaust from a spacecraft to create thrust. In 1998, *Deep Space 1* completed a highly successful flight test of ion propulsion, making history in the fall of 2001 when it performed a flyby of comet Borrelly. Ion propulsion is considered to be one of the top contenders for propelling scientific missions to the Jovian system (particularly Europa) and beyond. According to Dr. John Brophy of the Jet Propulsion Laboratory (JPL), ion propulsion systems make missions more affordable and scientifically more attractive by enabling the use of much smaller, lower cost launch vehicles, and by reducing flight times. Current research is focused on improving the time that ion engines can fire at full thrust, with the goal set at approximately one year at full power.⁶²

Hall-effect thrusters represent another promising electric propulsion technology. A Hall thruster is a device used for numerous in-space applications, including orbit raising, on-orbit maneuvers, and de-orbit functions. This technology was invented in the United States in the 1960s, but largely discarded by subsequent developmental programs. The Soviet Union, however, perfected the technology and utilized it for satellite control and propulsion on more than 100 spacecraft. Hall thrusters can provide superior force compared to conventional ion engines, further reducing trip times and operational life. NASA researchers Steven Oleson and John Sankovic describe the operations of the system as follows:

The Hall thruster consists of three parts, the thruster, the power processor, and the propellant system. A power processor is used to generate an electrical discharge between a cathode and an annular anode through which the majority of propellant is injected. A critical element of the device is the incorporation of a radial magnetic field, which serves to impart spin to the electrons coming from the cathode and to retard their flow to the anode. The spinning electrons collide with the neutral xenon [the propellant], ionizing it. The xenon ions are then accelerated from the discharge chamber by the electric potential maintained across the electrodes by the power processor.

⁶¹ Eric J. Lerner, "Plasma Propulsion in Space," *The Industrial Physicist* (October 2000).

⁶² Lyn Lepre, "The Incredible Ions of Space Transportation," *NASA Space Science Enterprise* (16 October 2000).

The Hall thruster operates nominally in the 1500 seconds specific impulse (Isp)⁶³ regime, but could theoretically achieve over 4000 seconds Isp.⁶⁴

The fully electromagnetic magnetoplasmadynamic (MPD) thruster represents yet another promising electric propulsion technology. Lerner describes the operations of the system as follows:

In an MPD thruster, a continuous arc flows radially outward from a central cathode to a coaxial anode. The interaction of the radial current with the azimuthal, circular magnetic field that it produces generates a Lorentz force that accelerates the plasma down the barrel of the electrodes and focuses it behind the end of the cathode.

The result is a thruster that can produce exhaust velocities in the 40 km/s range. More significantly, however, the MPD generates very high thrust density – ten times above Hall thrusters. The major shortcoming of this approach is the need for a large amount of electric current, which would require a fission reactor (raising safety concerns).⁶⁵

Space Sails

Solar sails and plasma balloons offer another technological avenue for making travel to the outer planets more feasible. These concepts eliminate the need for propellant, thus greatly reducing the size of exploratory spacecraft and greatly increasing potential payload size. The sun provides a tremendous energy source, and the pressure of sunlight could theoretically push a vehicle at 100,000 miles per hour (six times the speed of chemical systems). A solar sail would use this pressure in much the same way a sailing ship uses the wind. It would consist of a large sheet of reflective material, such as the Mylar film that is used to keep spacecraft from overheating, and a framework of girders to keep it extended and to transmit its pressure to the spacecraft. The largest challenge facing this concept is developing a system that can effectively unfurl an extremely large sail (perhaps kilometers in diameter) without damaging it. Regardless, the concept shows great promise for long-haul cargo missions to Mars or the outer planets (as well as interstellar science missions), where the size of the payload (and not necessarily time) is the most important factor in mission success. Research on this technology is being conducted both by NASA and commercial sector companies like Team Encounter.⁶⁶

⁶³ A performance parameter of a rocket propellant, expressed in seconds, equal to the thrust F in pounds divided by the weight flow rate \dot{W} in pounds per second: $I_{sp} = F / \dot{W}$. Specific impulse is also equivalent to the effective exhaust velocity divided by the gravitational acceleration.

⁶⁴ Lerner, "Plasma Propulsion in Space;" Steven R. Oleson and John M. Sankovic, National Aeronautics and Space Administration, Glenn Research Center, "Advanced Hall Electric Propulsion for Future In-Space Transportation."

⁶⁵ Ibid.

⁶⁶ Leonard David, "Advanced Propulsion Comes of Age," *Space.com* (29 May 2002).

Another promising concept is plasma balloons – a huge magnetic bubble generated aboard a planetary spacecraft and propelled by charged particles in the solar wind. Similar to solar sails, plasma balloons could send spacecraft to the outer planets far faster than conventional chemical rockets. For instance, the Mini-Magnetosphere Plasma Propulsion (M2P2) spacecraft being developed at the University of Washington could theoretically travel at speeds up to 180,000 miles per hour and reach the Jovian moon Europa in just 1.5 years (chemical systems would take 5 years). At this point, the concept is only being considered for small robotic vehicles – although it could potentially be used for human exploration as well. One advantage of the approach from the human perspective is that it would provide radiation protection for the crew during the long trip outward. The concept is at technical readiness level/TRL-4, which means it could be flight-tested sometime in the near future.⁶⁷

Aero-Assist Technologies

Vehicles utilizing aero-assist technologies employ the aerodynamic forces related to planetary atmospheric flight to control or alter relative velocity. There are three basic concepts in this arena:

- Slingshot Effect: use of an intervening planet's orbital energy to propel a spacecraft onward at a greater velocity. This approach has been used frequently on probes sent to explore the outer solar system.
- Aerobraking: using a planet's atmosphere to slow a craft to orbital speeds, this approach employs one or more passes through the atmosphere to reduce the apogee to the desired altitude – at which point a propulsive burn is made at apogee so as to raise perigee up out of the atmosphere and circularize the orbit.
- Aerocapture: similar to aerobraking, with the distinction that aerocapture is employed to reduce the velocity of a spacecraft flying by a planet so as to place the spacecraft into orbit about the planet, with only one atmospheric pass.

The advantage of this technique for planetary orbiters is that it permits spacecraft to be launched from Earth at high speed, allowing a short trip time, and thereby reducing the speed by aerodynamic drag at the target planet. Without aerocapture, a large propulsion system would be required to perform the same reduction of velocity, consequently reducing overall payload size. NASA researchers have proposed an aerocapture flight demonstration in Earth orbit for 2005.⁶⁸

Electrodynamic Tethers

⁶⁷ Robin Lloyd, "Solar Windsurfing: The Fastest-Ever Propulsion," *Space.com* (21 June 2001).

⁶⁸ "Advanced Propulsion Concepts," prepared by the Advanced Propulsion Technology Group at the Jet Propulsion Laboratory.

Space tethers are long cables in space that could be used to couple spacecraft to each other and allow the transfer of energy and momentum from one object to another. In-space tethers could act as “space tug boats” and enable key missions within a larger in-space transportation architecture. This technology would be particularly useful for boosting spacecraft to higher orbits around Earth, thus cheaply and efficiently pushing vehicles out of the gravity well. Several space tether test flights have been conducted during the past decade, and this continues to be an area of particular interest for NASA researchers. A NASA team is currently working with the University of Illinois at Urbana-Champaign, Tennessee Technological University at Cookeville, and Tethers Unlimited of Lynnwood, Washington to develop the Momentum Exchange, Electrodynamic Reboost (MXER) tether. The MXER would toss satellites into higher orbits, and could eventually send cargo and crew to the outer solar system.⁶⁹

VASIMR

The Variable Impulse Magneto-Plasma Rocket (VASIMR), being developed at the Johnson Space Center’s Advanced Space Propulsion Laboratory, could theoretically cut trip times to Mars from 9-months to just 3-months. Dr. Franklin Chang-Diaz, a veteran astronaut and primary researcher on the program, describes the concept as “a system using radio waves that heat rocket fuel – in this case hydrogen – to super hot temperatures.” The VASIMR rocket consists of three major magnetic cells, denoted as forward, central, and aft. To operate the rocket, a neutral gas (typically hydrogen) is injected at the forward end-cell and ionized. The ionized gas is then heated to the required temperature and density in the central-cell using electromagnetic waves (similar to what happens in microwave ovens). The resultant plasma (known as the fourth state of matter) then enters a two-stage hybrid nozzle at the aft end-cell, where it is exhausted to provide modulated thrust. The crucial VASIMR technology is its ability modulate the plasma exhaust while maintaining maximum power. The result is that the system is flexible enough to efficiently carry out slow cargo missions or fast human missions to Mars and the outer solar system. The primary challenge offered by VASIMR is containing the super hot plasma, which no known solid can accomplish. As a result, JSC researchers are experimenting with superconducting magnets to generate a field to hold the plasma.⁷⁰

Project Prometheus

In February 2002, NASA Administrator Sean O’Keefe unveiled the Nuclear Systems Initiative (NSI), a five-year, \$1 billion technology effort intended to lead to development of a uranium-fueled nuclear fission reactor with an advanced electric propulsion system. A nuclear propulsion system would be operated by using thermal energy from a fission reactor to heat a propellant working fluid (such as hydrogen), and then

⁶⁹ Ibid.; David, “Advanced Propulsion Comes of Age.”

⁷⁰ NASA Office of Spaceflight, “Variable Specific Impulse Magnetoplasma Rocket,” available from spaceflight.nasa.gov/mars/technology/propulsion/aspl/vasimr.html; Internet; accessed 8 November 2002; Glen Golightly, “Plasma Rockets Could Propel Man to Mars,” *Space.com* (16 June 2000).

expand the heated hydrogen through a nozzle to produce thrust. The space agency believes that NSI can address a number of problems that hinder long-range space exploration:

- Due to the long distances involved, many science “frontiers” are inaccessible (such as European subsurface ocean, Martian subpolar caps, Titan surface).
 - Thus, gaining access to the locations in the Solar System with the highest potential science payoffs or yields remains a challenge.
- Assessing “habitability” of other bodies in the Solar System presents extreme challenges (such as getting there, having power once there, returning scientific data).

The space agency argues that nuclear propulsion systems would offer practical solutions to these challenges, such as:

- Nuclear power and propulsion, based on fission, represents the only means within our reach to get to and explore many of the most compelling places in order to address driving science questions.
- Nuclear solutions for robotic exploration of the Solar System are evolvable to capabilities needed for human exploration of deep space in the future.

The conviction is that development of space-based nuclear systems will not only enhance in-space transportation, but will offer better options for surface operations. For instance, while solar energy can provide sufficient power for approximately 180-day surface stays on Mars, nuclear energy can provide sufficient power for more than 1,000-day surface stays.⁷¹

From the space propulsion and power perspective, nuclear systems provide a wealth of advantages over chemical propulsion, including:

- Greater ability to change speeds (like a powered airplane)
- Greater power for instruments (virtually unlimited)
- Greater ability to transmit science data to Earth
- No launch constraint to use aero-assist techniques
- Can orbit multiple objects on a single mission
- Can change target mid-mission to support changing priorities

⁷¹ Edward Weiler, National Aeronautics and Space Administration, Space Science Enterprise, “In-Space Propulsion/Nuclear Power,” (28 October 2002).

The flexibility offered by nuclear propulsion would enable a number of robotic exploration missions: Jupiter Icy Moons Orbiter (JIMO), Titan Orbiter & Atmosphere Explorer, Triton/Neptune System Orbiter, Kuiper Belt Object Reconnaissance, and Comet Chaser. For human exploration, the technology provides even greater mission opportunities.

- Nuclear power and propulsion are key enablers of expanded human exploration
 - Enables human exploration beyond Earth orbit
 - Provides high power for human protection against charged solar particles
 - Provides abundant power at destination
 - Enables complex, long duration missions
- Nuclear surface power is essential for extended reconnaissance of the Mars surface
 - Long-range surface and sub-surface exploration
 - Human habitat and life support
 - In-situ manufacturing of consumables
 - In-situ propellant production

In summary, the NASA argument in favor of NSI is that nuclear propulsion and power are enablers for future space science (and eventually human) missions not currently viable using conventional chemical systems.⁷²

Antinuclear Movement

While nuclear power and propulsion may make future space science and human exploration programs a reality, any effort to utilize these technologies is sure to encounter significant protest from the antinuclear movement. While antinuclear organizations like Global Network Against Nuclear Weapons and Nuclear Power in Space focus much of their efforts on the weaponization of space, they have also expressed concern regarding the safety of launching potentially dangerous nuclear material into space (especially after the technical failures that led to Shuttle *Columbia* accident). In 1997, when NASA launched the nuclear-powered Cassini spacecraft, the space agency faced objections from activists arguing that a launch accident or mishap during a planned flyby of Earth (en route to Saturn) could kill billions of people. Although the program admitted there was a small chance of negative health impacts, it contended that critics exaggerated the risks. Scientists stated that even if the 73-pounds of plutonium did explode in the atmosphere, “the radiation dose an individual would receive over a 50-year period from that exposure would be ... 15,000 times less than a natural lifetime exposure.”⁷³

⁷² Ibid.

⁷³ Robert Roy Britt, “Nuclear Power Poised for Re-Entry into Space,” *Space.com* (25 June 2001).

NASA researchers argue that the American public has been “badly misinformed by alarmists.”⁷⁴ Critics, however, point to past accidents involving spacecraft with nuclear elements, including:

- In 1964, the U.S. SNAP-9A spacecraft failed and reentered Earth’s atmosphere, jettisoning its nuclear payload over the Indian Ocean.
- In 1973, the Apollo 13 lunar module (which used a Radioisotope Thermoelectric Generators - RTG) broke up in the atmosphere upon reentry.
- In 1978, the U.S.S.R. Cosmos 954 spacecraft malfunctioned and crashed into western Canada, releasing thousands of highly radioactive fragments into a lake and surrounding area (no deaths have been related to the incident).

Proponents of the future use of nuclear power and propulsion contend that different nuclear technologies provide much greater safety than previously utilized systems. Unlike the NERVA/Rover, SDI, and SEI models:

...current interest in nuclear propulsion is focused on nuclear electric propulsion, and entirely different concept in which a small nuclear power plant produces electrical energy to power high-performance electric thrusters. The fact that these reactors are much smaller than commercial reactors and are closed to the environment makes this system much easier to test than open-cycle thermal rockets. In addition, safety features that could absolutely prevent inadvertent reactor startup in any credible launch accident would be much easier to implement with these types of reactors.⁷⁵

Regardless of the potential safety advantages of proposed nuclear power and propulsion systems, policymakers should expect dissent with relation to any programs using these technologies – there are scores of antinuclear groups with thousands of members dedicated to preventing these spacecraft from gaining approval. A revised NSTP could include policy language aimed at promoting the highest level of safety in these development programs to allay public protest.

Conclusion

This chapter reviewed relevant space policy, launch studies, and program planning to support the current revision of the National Space Transportation Policy, in accordance with National Security Presidential Directive/NSPD-15. In particular, it highlighted the features of current U.S. in-space transportation initiatives and analyzes their implications for the NSTP review. This review was utilized to generate

⁷⁴ Ibid.

⁷⁵ Ibid.

recommendations for policy language that could be used to address in-space transportation in a revised NSTP. Those recommendations include:

- “The National Aeronautics and Space Administration will pursue affordable, reliable, and timely transport of people, machines, and consumables across near-Earth and interplanetary space.
 - NASA will work to enable routine, flexible, and affordable voyages of people and machines to planetary surfaces.”
- “The National Aeronautics and Space Administration, to the degree possible, will establish a consistent level of funding for advanced and nuclear in-space propulsion programs to ensure that steady progress is made toward affordable, reliable, and timely in-space transportation capabilities.”
- “The National Aeronautics and Space Administration will establish an internal process to prioritize in-space transportation technology research and development.
 - This prioritization process will seek to match technologies with missions, ensuring that appropriate systems are developed for transport of people, machines, and consumables across near-Earth and interplanetary space.
 - This prioritization process will examine mission requirements across National Aeronautics and Space Administration strategic enterprises to ensure that the most critical needs are addressed by ongoing technology development programs.”
- “The National Aeronautics and Space Administration will adopt a balanced approach to research and development of advanced and nuclear in-space propulsion technologies, which meets the requirements for transport of humans, machines, and consumables.”
- “The National Aeronautics and Space Administration, where appropriate, will cooperate with the Department of Energy on nuclear propulsion and power technology research and development.”
- “The National Aeronautics and Space Administration will investigate opportunities for cooperation with the Russian Federation, and other countries where appropriate, on nuclear propulsion and power technology research and development.”
- “The National Aeronautics and Space Administration will establish processes that will promote the highest levels of safety in the use of nuclear propulsion and power technology.”

Based on our review of relevant space policy, launch studies, and current program planning, we believed that these policy language recommendations could be used to communicate the importance of addressing in-space transportation requirements within a revised policy.

APPENDIX A: MACRO-LEVEL SPACE POLICY TRENDS

This appendix provides an overview of several important macro-level trends that form the backdrop and context wherein the updated National Space Transportation Policy will likely be viewed by those familiar with the U.S. national security, civil, and commercial space sectors. Being cognizant of these trends will assist the policymakers in formulating appropriate guiding principles for space transportation research and development conducted by NASA and the DoD. The ultimate objective of understanding these overarching policy and programmatic movements is to inform the generation of productive and forward-looking policy language for a revised NSTP. These trends have impacts on each of the major policy thrusts that the White House has indicated will be the foundation of a revised policy – assured access to space, future space launch, and in-space transportation.

Failed DoD-NASA Cooperative Efforts

During the last several decades, attempts at major DoD-NASA cooperative development programs have demonstrated a poor record of success. Since the 1970s, DoD and NASA have engaged in several major cooperative development programs for space transportation systems. Most have met with failure and cancellation. The design of the one cooperative program that did result in a flight vehicle – the Space Shuttle – was driven in large part by a military requirement for cross-range gliding capability to enable the orbiter to return to the USAF’s West Coast launch site after a once-around mission to polar orbit. As a result of changes to national space transportation policy after the Shuttle *Challenger* accident, this capability was never used. Nevertheless, this unique military requirement drove the design of the orbiter’s wings, which in turn led to a significantly larger, heavier vehicle requiring more ascent performance than would have been required to meet NASA’s mission requirements. During the late 1980s and early 1990s, the nation invested more than \$4B on a joint DoD-NASA program called the National Aerospace Plane (NASP). This program was canceled, however, before any flight hardware was built or tested as a result of several factors: the inability of DoD and NASA to agree on a set of clearly-defined and sufficiently compelling mission requirements; significant technical challenges caused by an effort to make too large a technological leap; sizeable programmatic overruns; and the impact of the national budget deficit on overall space expenditures.

NASP was promoted not only as an X-plane technology demonstrator. It was also seen as a prototype of a multi-mission reusable space vehicle for the U.S. Air Force (USAF), a replacement for the Space Shuttle, and a commercial vehicle intended to carry passengers airline-style in what President Reagan referred to as the “Orient Express.” The multiple and varied requirements led to repeated redesigns and created tension among the participating agencies, which had different ideas about which capabilities were most important.

In 1989, Richard Cheney, the newly appointed Secretary of Defense, took a hard look at NASP. In June of that year, a study was conducted by RAND that noted continuing performance challenges and stated, "No compelling 'golden mission' exists for NASP."⁷⁶ At that point, the first flight had slipped a decade, and the total costs looked to be as much as 500% over the initial estimates.⁷⁷ Based on the RAND report and other inputs, Cheney decided DoD would no longer contribute to the joint effort, a decision that led to the program's cancellation – DoD had been contributing about 80% of the program's total budget. In addition to the cost problem, Cheney agreed with RAND there was no compelling DoD mission for the NASP, despite the fact that the USAF had consistently maintained there was.

In the late 1980s, DoD and NASA entered another cooperative program to develop a modern fleet of expendable launch vehicles (ELV) to satisfy both DoD and NASA requirements – the Advanced Launch System (ALS). After a few years of design and technology work, the DoD requirements for missile defense and the NASA needs associated with planetary exploration were scaled back and the program was renamed the National Launch System (NLS). The program was scaled back yet again in response to further changes in military and civil requirements, renamed Spacelifter, and subsequently canceled. With cost estimates as high as \$15 billion, these ambitious development programs had been focused primarily on improved performance, capacity, and responsiveness because of their potential to considerably relax design constraints and thereby reduce the costs and risks associated with spacecraft payload design and development. However, in light of both DoD's and NASA's shifting mission needs, it became clear that a much more affordable and evolutionary approach to launch system modernization made more sense and was more achievable.

Commercial Space Sector

The commercial space sector's projected boom in the late 1990s and subsequent bust has led to severe overcapacity in the global launch market. In the early 1990s, commercial launches were projected to remain far fewer in number than government launches, accounting for only a few additional U.S. launches per year. Commercial launch activity to geostationary orbit (GEO) grew from an average of 13 per year between 1991 and 1995, to an average of 21 per year between 1996 and 2000. In addition, the low Earth orbit (LEO) market emerged and commercial launches were projected to make up 40 percent of the manifest into the 21st century. However, by 1999, the commercial market had suffered several setbacks – notably the bankruptcy of Iridium – and it became clear the projected growth would not materialize. One consequence of the commercial market's projected boom and subsequent bust was that a wide variety of privately funded reusable launch vehicle (RLV) concepts proliferated during the 1990s, but none of these entrepreneurial ventures was able to raise sufficient funding to pursue development beyond initial design and a few subscale, subsonic atmospheric flight demonstrations. Most have ceased operation.

⁷⁶ Bruno Augenstein, *Assessment of NASP: Future Options* (Santa Monica, CA: RAND, June 1989), WD-4437-AF.

Since the National Space Transportation Policy of 1994 assigned DoD the lead role for evolving the nation's expendable launch vehicle (ELV) fleet, the USAF – in partnership with industry – has sponsored the development of two competing families of Evolved Expendable Launch Vehicles (EELVs). In 1997, in light of strong commercial satellite and launch market projections, the USAF adjusted its acquisition strategy for the EELV program to sponsor the development of both families of vehicles. With more private financing brought into the equation, the government contribution to the development of an EELV capability was reduced by half. Now, with much less robust commercial market projections, both EELV developers are concerned that they will not be able to recover their private investment over the coming years. In parallel with EELV development, the major U.S. launch companies entered into significant international partnerships to offer commercial launches using Russian and Ukrainian vehicles. This was an important development to enable the U.S. companies to address the growing portion of the commercial launch market made up of larger and heavier commercial satellites than those that could be launched by the only U.S. commercial launch vehicles available prior to the fielding of the EELV families. The consequence of these parallel development efforts, coupled with the introduction of the European Ariane 5 and the subsequent downturn in commercial market demand, is that the world capacity to conduct small launches (i.e., < 5,000 pound payloads) exceeds projected demand by a factor of seven and the capacity to conduct medium to large launches (i.e., payloads > 5,000 pounds) exceeds projected demand by a factor of almost two.⁷⁸

High Profile Failures

A series of high-profile failures, losses, and near misses in 1998 and 1999 raised concerns regarding the ability of the U.S. space sectors to assure access to space. Between August 1998 and May 1999, the United States experienced losses of \$3.5 billion worth of launch vehicles and spacecraft as a result of three government Titan IV-related launch failures and two commercial Delta III failures.⁷⁹ In addition, the Space Shuttle fleet was grounded for five months in 1999 and 2000 while NASA worked to find and repair damaged wiring systems. This series of failures, losses, and near-misses raised concerns regarding the ability of the U.S. space industry to sustain robust, assured, and reliable access to space for national security, civil, and commercial missions. Consequently, DoD, NASA, and industry undertook a series of internal and external reviews to identify the causes of these problems, recommend corrective actions to prevent their reoccurrence, and address the broader, systemic issues underlying their occurrence in the first place.

⁷⁷ "Proceedings of the RAND Project USAF Workshop on Transatmospheric Vehicles," 18-19 April 1995.

⁷⁸ "Space Industrial Base Study," Booz Allen Hamilton, 2000.

⁷⁹ "Space Launch Vehicles Broad Area Review," Lt Gen Les Lyles; available at www.af.mil/lib/misc/spacebar.html; Internet; accessed October 2002.

DoD's review focused on two areas and developed recommendations consistent with the industry reviews. First, DoD emphasized the importance of mission success in the fly-out of current (Titan IV, Atlas 2 & 3, Delta II) systems worth approximately \$20 billion in launch vehicle and spacecraft assets. Second, it addressed the transition to the EELV families, noting that the nation's future access to space depended on successful transition to EELV. Recommendations addressed the need for adequate technical support staff for the transition, a transition plan, and clear definition of end-to-end responsibility for delivery of spacecraft on orbit using EELVs.⁸⁰ The NASA-sponsored series of reviews pointed to the probable causes of the failures and specific management concerns that contributed to these losses. The agency noted, "It is important to recognize that space missions are a 'one strike and you are out' activity. Thousands of functions can be correctly performed and one mistake can be mission catastrophic." Paralleling one of DoD's findings, one review noted the "project manager must be responsible and accountable for all aspects of mission success."⁸¹ Several of these reports included observations regarding the importance of sustaining a qualified, adequately trained, and sufficiently experienced and mentored space workforce as a prerequisite for assuring access to space and consistently achieving successful space missions.

Dependence on Space Systems

While the U.S. has increased its dependence on space systems and capabilities over the past decade, the U.S. space industrial base has undergone significant consolidation, and the space sector's profitability has consistently been lower than the overall aerospace and defense industry.⁸² Over the past decade, as a result of flat or declining market demand, the space segments of U.S. corporations generally have not been profitable enough to recover the cost of capital. In this climate, growth in U.S. companies has been pursued primarily through acquisition, mergers, and divestitures. This process of acquisition and divestiture has kept the overall debt levels high in the major U.S. space companies. Despite this trend, U.S. space systems are increasingly enablers (as distinguished from enhancers) of terrestrial activities. All activity in space is made possible by reliable and cost-effective access to space. This has led to greater dependence on space launch systems and capabilities, with more users and uses. It has also led to increasing inter-dependence among the national security, civil, and commercial space sectors. Space transportation continues to be the most obvious area of overlap among the space sectors. This fact, combined with the lack of a national imperative to drive space-related investments and growth, has led to a situation where fewer space systems are being developed, built, and launched. This has resulted in fewer competitions for national security and commercial space systems with a "winner take all" nature. Industry is responding to this acquisition approach by forming teams before final down-selects.

⁸⁰ Ibid.

⁸¹ Thomas Young, "Mars Program Independent Assessment Team Summary Report," (March 2000).

⁸² "Space Industrial Base Study," Booz Allen Hamilton, 2000

To address this tendency, government agencies (particularly DoD) have taken steps to improve the competitiveness of the U.S. space industrial base by changing some aspects of their acquisition approach. Examples include:

- Adding an emphasis on industrial base assessments at milestone decision points to ensure the U.S. space industry will have sufficient expertise and capacity to deliver the required capabilities and compete for additional related work in the future
- Changing the “paid cost rule” to improve the cash flow for U.S. space companies
- Encouraging companies to refocus their independent R&D investments on actual technology work to enable the potential development of new capabilities in the future, as opposed to more focused development efforts addressing specific issues in support of a particular acquisition program to further the company’s competitive position in that individual procurement
- Relaxing R&D profitability guidelines
- Ensuring profit incentives do not reward maintaining excess capacity

These same factors have also led to a risk-averse development climate for national security and commercial systems. In addition, funding constraints and problems with cost overruns in current space programs have made it difficult to pursue the development of modernized capabilities while sustaining the current legacy systems.

RLV Failure

NASA’s most prominent X-vehicle reusable launch vehicle (RLV) technology demonstrators failed to deliver as planned. Since the release of the National Space Transportation Policy of 1994, NASA (in partnership with industry) has invested more than \$1.2 billion to design and build a series of X-vehicles to demonstrate reusable launch vehicle (RLV) technology. As noted below, both the X-33 and X-34 experienced significant delays and problems driven by technological challenges, and both have been abandoned completely as a result of neither being selected for continuation as part of NASA’s current second generation RLV effort under the Space Launch Initiative. Plans for the X-33 flight demonstration program – the NASA-Lockheed Martin flagship subscale demonstrator that was to have led to development of the commercial VentureStar single stage to orbit (SSTO) vehicle – were scaled back several times as technical problems relating to materials, structures, thermal protection systems, propulsion, and aerodynamic control made it clear the X-33 would not be able to fly as high or as fast as originally intended. Despite some success in developing and ground testing the RS-2200 linear aerospike engine, the demise of the X-33 was marked by a joint failure after a hydrostatic pressure test of its multi-lobed composite cryogenic propellant tank. In the summer of 2001, the USAF considered and rejected NASA’s offer to allow it to take over the X-33 flight hardware because it did not believe the demonstrator could offer any residual operational utility. The Orbital Sciences X-34 fell victim to problems with NASA’s

development of the propulsion system combined with USAF and NASA concerns regarding the adequacy of the flight demonstrator's design for reliability and safety. These X-vehicle demonstrator programs were ambitious from the beginning and they were recognized from the start as containing considerable technical risk associated with "pushing the envelope" to demonstrate RLV design and performance. It is unfortunate, if not unexpected, that the technology reach being pursued exceeded our grasp despite the considerable resources, effort, and innovation that were applied to the problems.

Complex Commercial Launch Market

International partnerships, Russian rocket engines on U.S. Atlas vehicles, foreign insurance underwriters, and tighter export controls under the State Department have combined over the past several years to produce a very complex environment for U.S. commercial space launch providers. Both Boeing and Lockheed Martin are long-term partners with foreign launch providers, and both market commercial launch services by offering a family of vehicles consisting of their domestic vehicles and foreign vehicles (i.e. Delta with Sea Launch, Atlas with Proton). Each company has found the foreign vehicles offer them more profit potential because less U.S. investment and overhead is involved in these marketing efforts as opposed to the development, manufacturing, and operation of domestic vehicles. It remains to be seen how each company will market its EELV variants now that they have versions with performance capabilities that overlap with the larger, more powerful foreign vehicles

Under Secretary of the USAF Mr. Teets recently indicated that the U.S. probably would not fund the development of Pratt & Whitney's domestic production line for RD-180 rocket engines for the Atlas EELV. That means all Atlas EELV launches carrying DoD and National Reconnaissance Office (NRO) payloads will be dependent on Russian RD-180 rocket engines. Even a commercial launch of a U.S.-built commercial satellite aboard a U.S.-built launch vehicle from a U.S. launch site requires insurance that almost always involves a foreign underwriter. This is due to the fact that most U.S. underwriters have made business decisions not to participate in the volatile commercial launch insurance market and U.S. law only includes a provision to indemnify launch operators for losses that exceed the amount required by the government. That means an export license is required for a commercial launch involving all U.S. hardware.

Summary of Recent Events

To summarize, the DoD and NASA have a poor historical record of success in pursuing major cooperative development programs, despite repeated efforts over the past 30 years. Over the past decade, the U.S. has become increasingly dependent on space-based capabilities, the U.S. space industry has undergone considerable consolidation and entered into international partnerships, and commercial markets have become more volatile. This has complicated prospects for cooperative arrangements between the government and commercial sectors. Since 1998, several failures and near-misses involving U.S. launch

systems have raised questions regarding the ability of the U.S. space industry to assure access to space for U.S. systems.

Elements of the Current Environment

DoD Acquisition Program Cost Growth

Several major DoD space acquisition programs have recently experienced extensive cost growth; raising concerns as to how well equipped the USAF is to manage large, complex space-related acquisition programs. During the 1990s, U.S. national security space systems tended to continue operating longer than their predicted design life. At the same time, new system acquisitions were being pursued with combined missions, increased complexity, more software requirements, and significant development challenges – leading to “winner take all” competitions. Combined with changes in acquisition rules, the result has been that several major space acquisition programs have experienced significant cost overruns, including the Space Based Infrared System (SBIRS)-High and Advanced Extremely High Frequency (AEHF) programs.

Booz Allen Hamilton recently completed an analysis to better understand the causes of acquisition growth on space systems and provide options for dealing with them.⁸³ Through both quantitative and qualitative analysis the study pinpointed the specific causal factors for development growth across the three phases of systems acquisition. They included:

- **Flawed Initial Program Planning:** characterized by optimistic assumptions, inadequate linkage to force structure mission area plans (i.e., the overall planning context for the development, operation, and coordinated employment of new military capabilities and the context in which a program’s military utility is measured to justify continued adequate funding relative to other priorities), too many critical performance parameters, inability to adapt to changing requirements, and insufficient focus on technical risk reduction (i.e., insufficient time and funding allocated within the acquisition strategy, plan, schedule and budget to address elements of the program that could lead to cost and schedule overruns because they depend on technical approaches that are not well-understood or characterized based on experience)
- **Competitive Environment:** characterized by overemphasis on bottom line cost versus cost realism, lack of understanding of requirements, and cost being used as the discriminator in acquisition decisions
- **Corporate Environment:** driving decisions relating to short-notice budget adjustments, diminished confidence in ability to execute according to plan, and limited flexibility to make cost adjustments as program content is better understood

⁸³ “Space Systems Development Growth Analysis,” Booz Allen Hamilton, August 2002.

- Acquisition Workforce Problems: including lack of program management continuity, gap in relevant experience because contractor has had more responsibility under total system performance responsibility (TSPR) approach, and eroded cost estimating capability

In October 2002, DoD notified Congress that the total cost of SBIRS-High “rose \$1.6 billion between December 30, 2001, and June 30, 2002, as a result of a new cost estimate by the Cost Analysis Improvement Group... In May, Pentagon acquisition executive Pete Aldridge certified to Congress that SBIRS-High is key to national security goals and that no other alternative program can meet its requirements. The certification was needed because the program has exceeded its cost estimate by over 25 percent, a breach of the Nunn-McCurdy law.”⁸⁴

Commercial Launch Industry Financial Difficulties

The U.S. space launch industry is experiencing financial difficulties that may require additional annual government investments to sustain both EELV competitors. Neither Lockheed Martin nor Boeing has captured the number of commercial launches that had been planned to justify its private investment in EELV development. As a result, Lockheed Martin has already convinced the USAF to allow it to eliminate from its EELV contract the West Coast launch capability and the full development and demonstration of a heavy lift capability. In early 2002, it also suggested that it might require an additional several hundred million dollars per year from the USAF to sustain its EELV capability. In July 2002, the USAF indicated its commitment to “maintaining two launch providers and to doing the right level of engineering and facilities work to assure our ability to deliver payloads to orbit.”⁸⁵

DoD and RLV Technologies

DoD has recently expressed interest in pursuing a larger and more active role in cooperating with NASA to pursue RLV technologies to meet its unique needs. Since the fall of 2001, DoD (primarily USAF Space Command) has been considering the prospects for expanding its participation in NASA’s Space Launch Initiative as a means of working toward the development of a reusable launch capability to serve national security needs for access to space. From November 2001 to February 2002, DoD and NASA conducted the 120-Day Study to examine the extent to which DoD and NASA requirements for an RLV intersect. As a result of the findings of the 120-Day Study and the Joint Requirements Oversight Council’s approval of the Operationally Responsive Spacelift Mission Need Statement, Space Command has advocated using FY 2003 funds to conduct an analysis of alternatives for operationally responsive spacelift. In addition, Pete Teets, Under Secretary of the USAF, has expressed his intent to cooperate more fully with NASA on RLV

⁸⁴ “Roche Says USAF Will Become More Involved in Managing SBIRS High Program,” *InsideDefense.com* (28 August 2002).

⁸⁵ “Competing Priorities May Keep Teets From Adding Major Dollars to EELV: Pentagon Finds Money for Big Ticket Items Scarce,” *Space News* (15 July 2002).

technology development.⁸⁶ Mr. Teets' military space deputy, retired Major General Robert Dickman, indicated it would likely take another 20 years before the USAF could field an operational military spaceplane, but that the USAF should plan to invest \$50 to \$100 million per year in RLV technology.⁸⁷

In October 2002, the memorandum of agreement chartering the DoD-NASA-NRO Partnership Council was formally expanded to include both the Commander of U.S. Strategic Command (USSTRATCOM/CC) and the Director for Research and Engineering (DDR&E), signifying a strategic alignment of the DoD's National Aerospace Initiative (focused primarily on the development and demonstration of hypersonic missiles using air-breathing and combined cycle propulsion systems) and NASA's Space Launch Initiative.

Shuttle Replacement

NASA still desires to replace Shuttle with an improved RLV, targeted at improving safety and reducing cost, but it has also decided to continue modernizing the Space Shuttle to keep it flying safely until 2020. In the summer of 2002, NASA began indicating that it was considering a substantial shift in the structure and focus of its Integrated Space Transportation Plan (ISTP) – the largest element of this plan being the Space Launch Initiative. This shift would entail consideration of relatively small and simple cargo and crew vehicles that could be launched atop EELVs,⁸⁸ as opposed to the larger stand-alone two-stage-to-orbit (TSTO) vehicles that had been recommended by several architecture studies conducted since 1998. In November 2002, NASA revealed the revised ISTP, which included three major elements:

- Flying the Space Shuttle until 2020
- Pursuing the development of next-generation reusable launch technologies
- Developing an Orbital Space Plane as soon as possible to provide crew transfer and assured access to the International Space Station (ISS) while providing an escape capability for a crew of seven.

This strategy leaves a significant gap between the end of the Russian agreement to employ Soyuz capsules as three-person crew return vehicles through 2006 and the expected 2010 delivery date for the first Orbital Space Plane to take over the crew return function. NASA has not yet made it clear how it intends to address this gap.

⁸⁶ Comments delivered during 8 October 2002 Town Hall meeting sponsored by Space Transportation Association.

⁸⁷ "USAF Space Deputy Says Operational RLV 20 Years Away," *Space News* (23 September 2002).

⁸⁸ "Reusable Space Transportation and Recovery System (RSTARS)," *Space News* (8 July 2002).

Space Launch Initiative

During the fall of 2002, NASA's SLI was restructured from its original plan. On 13 November, NASA announced that the agency was preparing changes to the FY 2003 budget request to refocus the SLI program to more tightly couple the Space Shuttle, Space Station, and SLI programs.⁸⁹ While the funding request for the new ISTP remains within the limits of the originally-planned FY 2003 budget for NASA, it reflects significant changes in the allocation of funding over the next five years. Some of the funding that had previously been planned for the ISTP will be shifted to the ISS program instead, and some will be shifted to keep the Space Shuttle fleet flying safely and reliably through 2020. The most significant effect on the SLI is that it no longer includes work to enable development of a second-generation RLV. Instead, it focuses on the Orbital Space Plane (based on current technologies) as the primary crew transport vehicle to and from the International Space Station, and next-generation launch technology work relating to propulsion, structures, and other key areas.⁹⁰

Near-Term Plans and Projections

Global Geosynchronous Earth Orbit (GEO) Launch Market

The U.S. share of the global commercial GEO launch market is likely to remain stable but small, with less than ten U.S. commercial launches per year, in the near future. Forecasts currently predict that the global commercial space launch market will remain stable, but relatively small, for the next several years. With that prediction in mind, it remains to be seen how Boeing and Lockheed Martin will market their mixed of EELV and foreign vehicles. It is clear, however, that current commercial market projections are insufficient to justify enough private investment to enable development of a next-generation RLV. Even if a second-generation RLV is capable of achieving a reduction in launch costs to \$1,000 per pound to orbit, it is unclear whether the commercial launch market is sufficiently elastic at that price point to result in dramatic market expansion. In 2000, an Andrews Aerospace study indicated that launch prices would have to be reduced to a few hundred dollars per pound to orbit before markets would expand sufficiently to raise the gross sales figures above today's levels for the U.S. launch industry.

DoD/NRO Modernization

DoD & NRO plan to modernize practically every national security space system in the coming decade, requiring a total investment of \$60 billion. Virtually every U.S. national security space system is scheduled to undergo modernization in the coming decade, requiring a total investment of roughly \$60

⁸⁹ NASA HQ Press Release, NASA Statement on the Integrated Space Transportation Plan, President's Budget Amendment, 13 November 2002, available at www.spacetransportation.com/news/istp.html; Internet; accessed 17 December 2002.

⁹⁰ NASA HQ Press Release, NASA's Integrated Space Transportation Plan Released, 13 November 2002, available at www.spaceref.com/news/viewpr.html?pid=9809; Internet; accessed 17 December 2002.

billion.⁹¹ As a result, if DoD intends to take advantage of the unique capabilities of an RLV, planned modernization acquisition programs must take these potential RLV or operationally responsive spacelift capabilities into account now and be appropriately time-phased to match the RLV development schedule.

Conclusion

To maximize its credibility while minimizing opportunities for criticism, an updated NSTP would contain clear themes and elements that reflect a complete appreciation of the macro trends and considerations outlined above. Specifically, the policy could address several major points that emerge from this review. First, if any cooperative effort between DoD and NASA is contemplated or directed in the policy, the policy could also clearly address how the cooperative effort is to be structured and executed to avoid the problems that have led to the failure and cancellation of previous cooperative efforts. Second, the weak condition of the U.S. space industrial base, coupled with the recent series of launch system failures, and increasing U.S. dependence on space could be pointed out as important considerations justifying specific measures to strengthen the ability of the U.S. to assure access to space. Third, the complexity, volatility, and overcapacity of the global commercial space launch market could be acknowledged and addressed as key considerations in any government space transportation strategies or programs whose success depends on cooperation with the commercial space sector. Finally, the substantial and growing federal budget deficit, and the fact that virtually every national security space system will be seeking funding for modernization in the coming decade, must be viewed as a major consideration in setting the direction, pace, and structure of any strategy or program to develop or improve U.S. space transportation capabilities for the future.

⁹¹ “Report of the Commission to Assess United States National Security Space Organization and Management,” January 2001, p. 62.

APPENDIX B: ADMINISTRATION THEMES

This appendix summarizes some of the important themes from several Bush Administration studies and reports that contain policy and strategy thrusts with relevance to a revised NSTP. These thrusts address several of the top-level themes that have driven the Administration's priorities and agenda. Examples addressed here include the overall approach to government, transformation of U.S. military capabilities, and re-focusing DoD, United States Air Force, and NASA priorities for space-related activities to reflect the existing political environment. The Bush Administration has clearly spelled out its overall approach to government in the FY 2002 President's Management Agenda. Major themes are highlighted for fourteen areas, including three that apply directly to space-related activities of the national security and civil space sectors. This paper outlines the relevant sections of the President's Management Agenda, and then addresses a series of more space-specific documents in chronological order, starting with the DoD Space Policy of 1999.

Prior to the 11 September 2001 terrorist attacks on the United States, Secretary of Defense Donald Rumsfeld "had directed [the leadership within the Department of Defense and the uniformed services] to engage in an intensive series of studies and debates about the proper path for modernizing and transforming our Armed Forces for the challenges of the 21st century." The most prominent example was the Quadrennial Defense Review (QDR). The emphasis of these studies and plans was on transforming U.S. national security capabilities and approaches for the present and for the future - an area the President had emphasized during his campaign, and a major theme of the Space Commission Mr. Rumsfeld chaired before his appointment as Secretary of Defense. Since taking office, the administration has appointed James Roche as Secretary of the Air Force, Peter Teets as Under Secretary of the Air Force and Director of the National Reconnaissance Office, retired Navy Vice Admiral Arthur Cebrowski as the Director of the DoD Office of Force Transformation, and Sean O'Keefe as NASA Administrator. Each of these appointees has clearly established priorities and themes for the U.S. national security and civil space sectors, based in large part on the thrusts established by the Administration.

The President's Management Agenda

The President's Management Agenda is a strategy for improving the management and performance of the federal government. The Agenda contains five government-wide and nine agency-specific goals to improve federal management and deliver results that matter to the American people. Several of these goals have specific relevance to the American space program. The following is a list of initiative headings (with associated quotes) that have applicability to aspects of the NSTP:

- Strategic Management of Human Capital

- "While the Administration will be seeking some targeted civil service reforms, agencies must make better use of the flexibilities currently in place to acquire and develop talent and leadership."
- Competitive Sourcing
 - "Nearly half of all federal employees perform tasks that are readily available in the commercial marketplace.... Historically, the government has realized cost savings in a range of 20 to 50 percent when federal and private sector service providers compete to perform these functions....
 - "To achieve efficient and effective competition between public and private sources, the Administration has committed itself to simplifying and improving the procedures for evaluating public and private sources, to better publicizing the activities subject to competition, and to ensuring senior level agency attention to the promotion of competition....
 - "In accordance with the Federal Activities Inventory Reform (FAIR) Act, agencies are assessing the susceptibility to competition of the activities their workforces are performing. After review by OMB, the agencies will provide their inventories to Congress and make them available to the public. Interested parties may challenge the omission or inclusion of any particular activity."⁹²
- Improved Financial Performance
 - "Improved accountability to the American people through audited financial reports. Financial systems that routinely produce information that is: timely, to measure and effect performance immediately; useful, to make more informed operational and investing decisions; and reliable, to ensure consistent and comparable trend analysis over time and to facilitate better performance measurement and decision making."
- Better Research and Development Investment Criteria
 - "Science and technology are critically important to keeping our nation's economy competitive and for addressing challenges we face in health care, defense, energy production and use, and the environment. As a result, every federal research and development (R&D) dollar must be invested as effectively as possible.
 - "The Problem: The federal government will spend approximately \$90 billion in 2001 on R&D, an investment representing 14 percent of all discretionary spending. The ultimate goals of this research need to be clear. For instance, the objective of NASA's space

⁹² On 17 October 2002, OMB released the first inventory, listing 75,000 civil service positions in 22 departments and agencies (including NASA) that could be outsourced under the 1998 FAIR Act. Agencies characterized 69% of their positions as "inherently governmental" and therefore not appropriate for outsourcing. OMB has provided budget guidance directing agencies to outsource 5% of their inventoried "non-core" jobs in FY 2002 and an additional 10 percent by October 2003.

science program is to 'chart our destiny in the solar system...' Vague goals lead to perpetual programs achieving poor results.

- "The federal government needs to measure whether its R&D investments are effective. We can rarely show what our R&D investments have produced, and we do not link information about performance to our decisions about funding. Without this information, decisions about programs tend to be made on the basis of anecdotes, last year's funding level, and the political clout of local interest groups.
- "The Administration is developing objective investment criteria for federal R&D projects. These criteria will also be used to assess the performance of research programs. A well directed R&D portfolio should demonstrate progress towards the portfolio's strategic goals, without necessarily expecting success from each and every project.⁹³
- "New applied research and development proposed in the 2003 Budget will be expected to perform in the top 25 percent of the program's existing R&D, with the goal of improving the quality of the research portfolio.
- "Application of the criteria will provide a benchmark for future performance assessments that will inform funding beyond 2003.
- "The Expected Long-Term Results: The Administration expects that these investment criteria will better focus the government's research programs on performance. The effectiveness of the U.S. government's R&D investment will be measurably improved over a period ending three years from initial benchmarking. Applied research programs will be better focused on achieving well-defined practical outcomes. Basic research programs will better target improving the quality and relevance of their research. These investment criteria will promote our nation's leadership in important science and technology areas."

DoD Space Policy of 1999

On 9 July 1999, Secretary of Defense William Cohen signed an updated DoD space policy directive (DoDD 3100.1). While not a Bush Administration policy document, many of the themes that are reflected in the Bush administration's policy and strategy documents have their origin in that directive. The DoD Space Policy of 1999 was the first update of DoD space policy since 1987, and addressed "major changes that have taken place since the last update, including the transformation of the international security environment; the promulgation of new national security and national military strategies; changes in the resources allocated to national defense; changes in force structure; lessons learned from the operational

⁹³ It is worth noting that, by their very nature, some research programs fail to produce predictable results because they are designed to explore the feasibility of new concepts, ideas, and approaches. While these experiments could be considered failures in terms of their original goals, they could also lead to successes in other, unexpected areas, or at least contribute to success in other areas.

employment of space forces; the global spread of space systems, technology, and information; advances in military and information technologies; the growth of commercial space activities; enhanced intersector cooperation; and increased international cooperation." Overall, the 1999 DoD Space Policy appears to be solidly based on the "space control" doctrinal perspective regarding space power. It appears to purposely stop short of including elements that would reflect the "high ground" doctrine. As such, while not explicitly advocating the development of force application capabilities, it does acknowledge the possibility that force application systems could be developed, tested, and operated at some point in the future. Its in-depth treatment of the other three mission areas (i.e. force enhancement, space support, and space control), coupled with its obvious exclusion of the force application mission area from these detailed lists, implies that DoD's near- to mid-term priorities will continue to align with traditional space mission areas. As a result, advocates of force application capabilities that could be conducted using a Reusable Launch Vehicle (RLV) will be expected to prove the worth of these systems relative to other land-, sea-, and air-based alternatives. The following provides a recap of some of the specific themes reflected in the 1999 DoD Space Policy.

- Space Control
 - Space power is as important to the nation as land, sea, and air power. The 1999 DoD Space Policy clearly reflects the "space control" doctrinal view, as does the September 2001 Report of the Commission to Assess United States National Security Space Management and Organization. Secretary Cohen's cover letter noted "the increasing importance of space activities to the security and defense of the United States" and referred to space as "a medium . . . [where] military activities will be conducted to achieve U.S. national security objectives." It went on to say "space power is as important to the nation as land, sea, and air power," pointing out the importance of space forces to "help enable the United States to establish and sustain ... battlespace dominance and information superiority." It pointed out that freedom of space and protecting U.S. national security interests in the medium are much like the high seas and international airspace. It also noted that space forces are "integral to the deterrent posture of the U.S. ... contribut[ing] to the overall effectiveness of U.S. military forces ... [as] force multipliers."
- Primary DoD Goal for Space
 - The primary DoD goal for space and space-related activities is to provide operational space force capabilities to ensure that the United States has the space power to achieve its national security objectives. The policy lists specific ways "space activities shall

Consequently, this federal government approach — requiring research programs to meet strict performance criteria — has the potential to unnecessarily constrain research or dampen creativity.

contribute to the achievement of U.S. national security objectives," including: U.S. self-defense and defense of allies; assuring mission capability and access to space; deterring, warning, and defending against enemy attack; ensuring the U.S. can conduct space activities and that hostile forces cannot prevent such use; enhancing operational effectiveness; countering, if necessary, space systems used for hostile purposes; satisfying military and intelligence requirements; and supporting a variety of government customers. This list clearly addresses the space support, force enhancement, and space control mission areas, but stops short of endorsing the immediate development of force application capabilities.

- New Space-Based Capabilities
 - DoD should consider new space-based capabilities when they offer operational advantages, and demonstrate technologies to address mission area deficiencies. The policy established a threshold for considering new space capabilities by stating "Space shall be considered as a medium of conducting any operation where mission success and effectiveness would be enhanced relative to other media." With regard to demonstrations and experiments, the policy stated "Technology applications that address mission area deficiencies shall be demonstrated. Such demonstrations shall involve both the developmental and operational elements of the DoD Components and shall be pursued to identify the value of emerging technology to the warfighter and the national security community." With regard to operations, the policy clearly focused on the space support, force enhancement, and space control mission areas while ignoring the force application mission area.
- Keep Options Open
 - In addressing arms control matters, DoD should seek to keep options open for the future. The policy stated that "Positions and policies regarding arms control and related activities shall preserve the rights of the United States to conduct research, development, testing, and operations in space for military, intelligence, civil, and commercial purposes, in accordance with [the President's 1996 National Space Policy (PDD/NSC-49, PDD/NSTC-8)]."

Report of the Commission to Assess United States National Security Space Management and Organization

The Report of the Commission to Assess United States National Security Space Management and Organization (Space Commission Report), released 11 January 2001, contained some important themes for U.S. space policy. While the Space Commission Report was not an official statement of Administration

policy, it is nevertheless authoritative because the Commission's chairman, Donald Rumsfeld, is now the Secretary of Defense. The following summarizes the findings of the Space Commission Report.

- Transformation
 - Space systems can help speed the transformation of the U.S. military into a modern force capable of deterring and defending against evolving threats. The Commission recommended a revision of national space policy that would foster the employment of "space systems to help speed the transformation of the U.S. military into a modern force able to deter and defend against evolving threats directed at the U.S. homeland, its forward deployed forces, allies, and interests abroad and in space."
- Vulnerability and the Need for Space Control
 - Our dependence on space systems makes us vulnerable to a "Pearl Harbor in space," so we should pursue space control capabilities as a means of deterring and defending our space capabilities. The report emphasized the U.S. dependence on space systems and warned of the need for space control capabilities to avoid a "space Pearl Harbor" in which adversaries attacked U.S. space systems to damage American military capabilities and the U.S. economy. It is this aspect of the report, indicating agreement with the space control doctrine, that has attracted the most attention.
- Weapons in Space
 - Space is the ultimate high ground, and "the U.S. government should vigorously pursue the capabilities called for in the National Space Policy to ensure that the President will have the option to deploy weapons in space to deter threats and, if necessary, defend against attacks on U.S. interests. In the Executive Summary, the commissioners stated that they "appreciate the sensitivity that surrounds the notion of weapons in space for offensive or defensive purposes. They also believe, however, that to ignore the issue would be a disservice to the nation. The Commissioners believe the U.S. government should vigorously pursue the capabilities called for in the National Space Policy to ensure that the President will have the option to deploy weapons in space to deter threats and, if necessary, defend against attacks on U.S. interests." The capabilities called for in the 1996 National Space Policy include space force applications. The report further states that, "Improvements are needed in the areas of ... Power projection in, from, and through space." This was a clear endorsement of the high ground doctrine. The Space Commission Report did not go to the level of recommending development of specific systems to enable the space force application mission. It did, however, offer the strongest high-level endorsement to date of the high ground argument (and the belief in the legality and the utility of weapons delivered, in, from, and through space) and place the current Secretary of Defense in a position of support for that theory.

Quadrennial Defense Review (QDR)

The 30 September 2001 report documenting the Quadrennial Defense Review (QDR) is the most comprehensive current strategic planning document for the Department of Defense (DoD). Though much of the work that went into the QDR was completed before the September 11th terrorist attacks on the United States, it was finalized and published in the aftermath of those tragic events. The QDR report provides a comprehensive description of DoD's revised mission, goals, and policy objectives in the current domestic and international environment – a political backdrop that has been dramatically transformed in a very short time. It restores the defense of the United States as the Department's primary mission and it emphasizes homeland defense, the unpredictable nature of the global threat environment, preparing for asymmetric threats, and the need for a capabilities-based strategy. At the highest level of abstraction, the QDR report says, "America's goals are to promote peace, sustain freedom, and encourage prosperity.... The purpose of the U.S. Armed Forces is to protect and advance U.S. national interests and, if deterrence fails, to decisively defeat threats to those interests." Four key defense policy goals establish the framework for U.S. military strategy:

- Assuring allies and friends of the United States' steadiness of purpose and its capability to fulfill its security commitments;
- Dissuading adversaries from undertaking programs or operations that could threaten U.S. interests of those of our allies and friends;
- Deterring aggression and coercion by deploying forward the capacity to swiftly defeat attacks and impose severe penalties for aggression on an adversary's military capability and supporting infrastructure; and
- Decisively defeating any adversary if deterrence fails.

The foreword of the QDR report, signed by Secretary of Defense Donald Rumsfeld, noted that "we cannot and will not know precisely where and when America's interests will be threatened . . . Adapting to surprise - adapting quickly and decisively - must therefore be a condition of planning." The following summarizes some of the key findings of the QDR.

- Capabilities-Based Defense Planning
 - A central objective of the QDR was to shift the basis of defense planning from a 'threat-based' model that has dominated thinking in the past to a 'capabilities-based' model for the future. Secretary Rumsfeld explained that this shift "requires that the nation maintain its military advantages in key areas while it develops new areas of military advantage and denies asymmetric advantages to adversaries. It entails adapting existing military capabilities to new circumstances, while experimenting with the development of new

military capabilities.... The challenges the nation faces ... involve ... projecting and sustaining U.S. forces in distant anti-access environments. They entail assuring ... rapid engagement of adversary forces and capabilities."

- Space Control
 - Ensuring the freedom of access to space and protecting U.S. national security interest in space are priorities for the Department. The QDR report clearly reflects the space control doctrinal view. It says, "Space and information operations have become the backbone of networked, highly distributed commercial civilian and military capabilities. This opens up the possibility that space control - the exploitation of space and the denial of the use of space to adversaries - will become a key objective in future military competition.... DoD must also undertake high-fidelity transformation exercises and experiments that address the growing challenge of maintaining space control ... DoD will establish a space test range for this purpose.... [T]he Department will treat.... space assets not simply as enablers of current U.S. forces but rather as core capabilities of future forces."
- Reorientation of U.S. Military's Global Posture
 - DoD plans to reorient the U.S. military global posture by employing globally-available in-space capabilities and forces to address anti-access and area-denial threats. The QDR report explains how DoD plans to reorient the U.S. military's global posture. It emphasizes addressing new challenges, particularly anti-access and area-denial threats, by employing globally available reconnaissance, strike, and command and control assets. It also notes, "Capabilities and forces located in the continental United States and in space are a critical element of this new global posture."
- Transformation-QDR Definition
 - [T]he evolution and deployment of combat capabilities that provide revolutionary or asymmetric advantages to our forces. The QDR states that "Transformation results from the exploitation of new approaches to operational concepts and capabilities, the use of old and new technologies ... that render previous methods of conducting war obsolete or subordinate.... [S]mall transformed forces with a critical mass of spearhead capabilities can produce disproportionate strategic effects."

The President's Commitment to Transformation of the Military

In a post-QDR speech on defense, given 11 December 2001, President Bush reiterated the emphasis on transforming the military. Concerning the threats to be countered, he remarked that, "Almost every state that actively sponsors terror is known to be seeking weapons of mass destruction and the missiles to deliver them at longer and longer ranges." In response, he said, "The first priority is to speed the transformation of

our military." Referring to an earlier speech, he reiterated his intent to "promote the peace, by redefining the way wars will be fought." He singled out unmanned vehicles as examples of technology for which he would increase funding, noting, "We're entering an era in which unmanned vehicles of all kinds will take on greater importance - in space, on land, in the air, and at sea."

DoD's Office of Force Transformation

On 27 November 2001, the Director of the newly-formed DoD Office of Force Transformation, retired Navy Vice Admiral Arthur Cebrowski, held a press briefing to explain the purpose of his office and the importance of transformation within DoD. He began by noting:

First and foremost, the President and the Secretary [of Defense] elevated transformation quite rightly to the level of strategy.... Strategy is about how one selects a competitive space [i.e., area or realm] and determines the competitive attributes within that space which will lead to advantage. Strategy answers the fundamental questions of how one controls the scope, pace and intensity of a competition.

Vice Admiral Cebrowski further argued that transformation is a vehicle for:

- Maintaining the asymmetric advantages of the U.S. military
- Managing risks associated with unpredictable future threats by expanding our capabilities base, our technology base, and our industrial base
- Operational prototyping to inform decisions and overcome cultural impediments to transformation within the military

He explained that the Office of Force Transformation plans to address five broad areas: strategy, concept formulation, technology, experimentation, and operational prototyping. Within the broader context of DoD's corporate strategy, he emphasized the importance of pursuing transformation to "expand the boundaries of current competencies ... to perhaps create new competitive advantages" and create new capabilities that can change DoD and the world. He cited examples where DoD has done this in the past, by introducing satellite communications, and by deploying nuclear ballistic missiles in submarines, satellite navigation, and stealth. The challenge is to create an environment that encourages and catalyzes the kinds of activities that can produce those kinds of changes.

Air Force Priorities for Space

In a November 2001 speech to the Air Force Association National Symposium, Secretary of the Air Force Roche spelled out his primary priority areas for the Air Force by saying, "My focuses fall into four general

categories: strategy, people, efficiency and the industrial base." In elaborating on this list, he explained the relevance of space by noting "Our performance in the space arena will prove to be a key indicator of how well the Air Force as a whole will fulfill our responsibilities in the 21st century." Secretary Roche went on to explain his four specific priorities for space within the Air Force:

- Strategic Roadmap for Air and Space Integration: Adjust strategic parameters to fit the challenges and opportunities of a new security environment, emphasizing global reconnaissance and strike, through a roadmap to integrate air and space operations.⁹⁴
- Professional Space Cadre: Career progression, educational opportunities, other tangible measures.
- Best Practices for Acquisition: Best business practices, including partnering with industry, as was done with EELV.
- Creating Incentives for Innovation: Critical need for more incentives to industry for innovation.

Defense Planning Guidance (DPG)

The latest DPG was released in May 2002. It built on the four strategy goals established for DoD in the QDR. The DPG established six operational goals, one of which directly related to the "space control" theme in the Space Commission and QDR reports:

- Protect critical bases of operations
- Project and sustain US forces in distant anti-access/area-denial environment
- Deny enemies sanctuary
- Assure information systems & conduct information operations
- Enhance capability/survivability of space systems
- Leverage information technology for joint C4ISR (e.g., joint operational picture)

The DPG also explains the framework for change in U.S. warfighting capability by highlighting five major transformational themes:

- From Threat Based To Capabilities Based Planning
- From Two Major Theater War Strategy To "4-2-1" Planning Construct (i.e., four simultaneous forward-presence missions designed to dissuade and deter, plus two lesser contingencies in overlapping timeframes designed to swiftly and decisively defeat adversaries, plus one larger

⁹⁴ Air Force Chief of Staff General John Jumper has also strongly advocated the critical importance of creating an overarching concept of operations as the first step toward truly integrating air and space systems. He argued for a fundamental shift toward a "capabilities based" approach to programming and budgeting that focuses on task forces to address particular mission areas, like global strike. General Jumper suggested that a better approach would be for a mission (e.g., time-critical targeting - whether it relies on air, space, manned, or unmanned systems) to be pursued under a program element.

- operation directed toward occupation or regime change-all while also sustaining homeland security)
- From Deliberate Planning To Adaptive Planning
- From Mass and Material for Eventual Superiority To Targeted Effects for Early Superiority (i.e., swiftly defeat)
- From Broad-based Political-Military Engagement To Focused Security Cooperation

National Security Strategy of the United States of America

On 20 September 2002, the President issued the updated National Security Strategy. Its primary themes include:

- The U.S. national security strategy will be based on a distinctly American internationalism that reflects the union of our values and our national interests. The aim of this strategy is to help make the world not just safer but better. Our goals on the path to progress are clear: political and economic freedom, peaceful relations with other states, and respect for human dignity.
- To achieve these goals, the United States will: champion aspirations for human dignity; strengthen alliances to defeat global terrorism and work to prevent attacks against us and our friends; work with others to defuse regional conflicts; prevent our enemies from threatening us, our allies, and our friends, with weapons of mass destruction; ignite a new era of global economic growth through free markets and free trade; expand the circle of development by opening societies and building the infrastructure of democracy; develop agendas for cooperative action with other main centers of global power; and transform America's national security institutions to meet the challenges and opportunities of the twenty-first century.

The only direct reference to space capabilities appears in a paragraph addressing a new U.S. military interest in Afghanistan post-September 11th. This section concluded by referring to a space control theme by noting that "military capabilities must also include the ability to defend the homeland, conduct information operations, ensure U.S. access to distant theaters, and protect critical U.S. infrastructure and assets in outer space."

NASA Administrator's Priorities

NASA Administrator Mr. Sean O'Keefe has been widely quoted as saying he has three fundamental goals for NASA, and that "if it doesn't fit those three goals, it doesn't fit at NASA." He is also reportedly focusing on the process of developing a revised vision statement for NASA and on implementing the President's Management Agenda within NASA. NASA's three fundamental goals are:

- Understanding and protecting the Earth.
- Exploring the universe and searching for life.
- Inspiring the next generation of explorers.

Conclusion

To maximize its credibility within the administration, an updated NSTP would clearly reflect a set of themes and approaches that make it consistent with other Bush administration policies and strategies. In particular, encapsulating two major themes would improve its chances of finding acceptance within the space policy community. First, reflecting the space-related sections of the President's Management Agenda could increase the likelihood of NASA acceptance of the new policy direction – helped by the fact that NASA Administrator Sean O'Keefe authored the President's Management Agenda when he was Deputy Director of OMB. Second, transformation has become a watchword within the DoD and integrally fits into the military space agenda – as highlighted by the Rumsfeld Commission and subsequent DoD policy documents.

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